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REDUCING REQUIREMENTS ERRORS THROUGH THE USE OF COMPUTER-AIDED SOFTWARE ENGINEERING (CASE) TOOLS DURING REQUIREMENTS ANALYSIS

THESIS

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The opinions and conclusions in this paper are those of the *author and are not intended to represent the official* position of the DoD, USAF, or any other government agency.

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Preface

This study was undertaken to learn if Computer-Aided Software Engineering (CASE) tools for requirements analysis were being used extensively in the United States Air Force (USAF) and whether or not any cost savings or growth could be associated with their use or non-use. The findings of this study may impact CASE tool use in the USAF and can serve as the foundation for future CASE tool studies.

During the course of completing this thesis, I received guidance and assistance from many people. A thank you to everyone who aided this effort. There are certain individuals who deserve a special acknowledgment. A tremendous THANK YOU goes to my advisor, Lt Col Patricia Lawlis, whose insight, patience, and encouragement kept me going throughout the proposal and thesis process. I would also like to thank my reader, Dr. Freda Stohrer, for her help in saying it in just the right manner and enabling me to get my point across. Thanks also goes to Professor Dan Reynolds for his assistance in setting up and reviewing all of the statistics and making mathematics fun again. Additionally, I would like to thank the Software Engineering Professional Continuing Education staff and Capt Joe Mattingly for their assistance in data collection, without which the study would have been impossible to complete. I would also like to thank the members of GSS-91D for their

ideas, support, and assistance throughout the entire process. Last, but certainly not least, I would like to extend my eternal love, appreciation, and thanks to my wife, Kelly, and our children, David, Sarah, and Andrew, who tolerated and endured my extended absences, odd hours, and late nights in the basement office over the last 18 months. God bless all.

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Abstract

This study investigated whether using CASE tools in the requirements analysis phase of software development reduced the software coding errors attributable to requirements analysis. A survey of the population gathered data as to the current practices and efforts in the use of CASE tools. The data was gathered in two groups: a control group and a sample group. The data was analyzed by group and in various combinations to obtain a greater understanding into the population trends and tendencies. The results of the research indicate that the Air Force does not use CASE tools to any great extent. Also, error and cost data are not tracked in a meaningful way either. The conclusion drawn from this research shows that CASE tool use is still in its infancy and needs to begin rapid growth in order to speed up developments and reduce costs with the constantly shrinking budget. The major recommendation by the author is to perform a more detailed study of the population to determine exactly where CASE tools are being used and where improvements need to be made.

REDUCING SOFTWARE ERRORS

THROUGH THE USE OF COMPUTER-AIDED

SOFTWARE ENGINEERING (CASE) TOOLS

DURING REQUIREMENTS ANALYSIS

I. Introduction

Background

Lt Cmdr John Richard Frost stated in his 1984 thesis at the Naval Postgraduate School:

> In the late sixties it was realized that the importance of software was rapidly exceeding that of the hardware on which it was implemented. This was manifested by sharply escalating software costs while the cost of hardware underwent dramatic decreases. The reduced cost of computers increased the demand for them and hence their numbers and the number and variety of applications in which they were used also increased. There was a growing demand for the ability to convert existing applications software to make it executable on the newer, more powerful, and less expensive hardware. The complexity and size of new applications also increased significantly with corresponding increases in the complexity and size of the software need to support them. This, in turn, led to a far greater demand for software than the existing software industry could supply. (Frost, 1984:7)

Today, software users are demanding more power in lap-top computers than the overall power of most early computers. Software projects have become enormous and extremely complex. "Simply put, the fundamental challenge facing

(Phillips, 1989:64). To assist the future software engineer in managing this growing complexity, today's engineers are creating automated tools to simplify the software management and development process. These products are called Computer-Aided Software Engineering (CASE) tools.

CASE tools can be used throughout the software lifecycle from conception to retirement. The research documented in this thesis centers on the use of CASE in the requirements analysis phase.

General Issue

Analysis of a problem is never easy. Finding errors early in the design process can save thousands, if not millions, of dollars (Bergland and others, 1990:8). CASE tools give engineers more freedom to try various methods of problem analysis in a shorter period of time. With them, engineers can also implement requirements changes faster and with less cost.

The federal government, specifically the Department of Defense (DoD), now needs, more than ever, to save money. CASE tools can provide a great deal of savings now. As a team of American Telephone and Telegraph (AT&T) software engineers pointed out:

> Our goal in applying new and existing technologies is to mechanize much of the front-end process and thus reduce development costs and improve product quality (Bergland and others, 1990:7)

AT&T has become one of the leaders in CASE tool use in the civilian community. DoD should embrace the ideas and concepts of AT&T by implementing efforts to reduce cost and speed up production. Software development will cost the Department of Defense (DoD) over $30 billion in FY 91. (Ferens, 1991:4) This cost translates to over ten percent of the total DoD budget for the year. As software acquisition grows, the DoD must find and use more cost effective ways to develop new software.

Specific Problem

Software development includes requirements analysis, design, coding, testing, and follow-on maintenance. This research examined the requirements analysis phase of software development. Specifically, the research, described in this thesis, focused first on the problem of time and money lost as a result of errors made during requirements analysis conducted without the assistance of Computer-Aided Software Engineering (CASE) tools and second on the effects tool use can have in reducing these losses.

Hypothesis and Investigative Questions

The hypothesis for the thesis research is that CASE tool use during requirements analysis correlates directly to a reduction of errors attributable to poor requirements analysis, thereby reducing deficiency and/or error

correction in later stages of a project. This hypothesis will be supported by answering the following questions:

1. What percentage of DoD software developers use CASE tools during the requirements analysis phase of project development? What percentage do not use CASE tools?

2. For what reasons did agencies choose to use CASE tools or not to use CASE tools?

3. What was the project size (lines of code, cost)? Was project size a factor in deciding whether or not to use CASE tools on the project?

4. What were the initial costs of using the tools? Follow-on or recurring costs?

5. What cost savings were found by using CASE tools over not using CASE tools (including the recovery of the initial costs)?

6. What errors were found? When? Did using CASE tools reduce the number of errors?

Scope of Research

This thesis research covered the use of CASE tools during the requirements analysis phase of a software development project. Which agencies use CASE tools and why users chose to use the tools were questions analyzed. Agencies that chose not to use tools and their reasons or lack thereof were examined. Whether project size and/or cost plays a significant role in the choice to use or not to

use CASE tools was reviewed. A cost-benefit analysis on the use of and non-use of CASE tools was performed. The analysis included initial start-up costs, training, recurring costs, savings from the use of tools, and recovery of costs.

This analysis did not include the specific CASE tools being used. To advocate one tool over another is not the issue here. CASE tool use in later stages of the software development process (i.e., design, coding, testing, and maintenance) was not reviewed in any detail. These areas were highlighted as necessary, however.

The next chapter reviews current literature on CASE tools. The review concentrates on the major highlights of CASE tool research and development. Chapter III reviews the methodology used to perform the research (i.e., population definition, data collection, etc.). Analysis of the collected data is the focus of Chapter IV. Chapter V summarizes findings and conclusions from the analysis. Appendices A through I represent the survey instrument development process and the data analysis calculations.

II. Literature Review

Introduction

Case tools are fast becoming the way to do business in the software engineering field.

> CASE techniques offer a unique opportunity to decrease the backlog of applications development. They also present an opportunity to increase the quality of systems being developed through consistent use of a standard methodology throughout the life of the software. (Batt, 1989:6)

Just as a carpenter needs saws, hammers, drills, and planes, the software engineer requires a tool box to make the job easier and more creative. Soon, CASE tools will fill the software engineer's toolbox. An understanding of the requirement for CASE tools and their continued creation and enhancement is needed before one can fully appreciate the importance of CASE tools. This review is directed toward an understanding of the software management problem, the benefits derived from the use of CASE tools, USAF CASE tool evaluation assistance, USAF CASE tool studies, and the direction for future tool developments.

Software Management Problems

A software engineer faces a myriad of obstacles and challenges in managing current software projects. Complexity, requirements definition, and cost stand between the engineer and successful completion of a project.

Today's complexity of software design is compares to the complexity of building the Space Shuttle. Many software projects "contain several million lines of code" (Bergland and others, 1990:8). No longer will programs of 100 to 10,000 lines of code be adequate. In describing the tools of software engineers, Barry Phillips states:

> At the 1988 Design Automation Conference, Andy Rappaport, president of Boston's Technology Research Group, said that 30% of embedded systems ran over 75,000 lines of code - up from 14% in 1985. What's more, the average size of programs that run on internally developed target hardware has nearly tripled. (Phillips, 1989:65-66)

Also, learning how to develop the complex code can be an education all by itself. Stuart Feil points out that:

> ...the original developer's tool kit for the OS/2 operating system and its Presentations Manager GUI included 29 manuals, 130 disks and eight video cassettes. That's more than an evening's reading. (Feil, 1989:57)

Learning the OS/2 operating system is equivalent to an advanced degree program.

As complex as software has become, software engineers face other problems. Understanding the ideas of others is a major stumbling block in requirements definition. AT&T developers have found:

> Traditionally, we have relied on natural-language (e.g. English) documentation as a communications medium. However, when written in English, requirements are often ambiguous and open to misinterpretation. (Bergland and others, 1990:9)

Human efforts in requirements translation lead to oversight and costly re-engineering of many software projects.

High costs prohibit many new software projects or updates to older software. Small firms do not have the resources or funding needed to invest in a major software build. Consequently, many small firms are forced to operate with outdated software that is difficult to use and costly to maintain; at times, they operate with no software at all.

Benefits of CASE Tools

Even though the software engineer faces many problems, hope is on the horizon.

> The combined effect of CASE tools and sound development principles should enable accelerated software development and lead to easing what has been referred to as a "Software Development Crisis." (Batt, 1989:1)

CASE tools can help avoid the problems of today's software projects in that the tools help do the job right the first time. As part of a special Datamation/Price Waterhouse opinion survey, Norman Statland comments:

> The improvements will stem directly from the decreased maintenance and increased productivity that will accrue over the total life of a system developed with CASE tools. (Statland, 1989:32)

Benefits from CASE tool use also include improved up front analysis, improved documentation, and increased productivity.

Analysis of a problem is never an easy task. Finding errors early in the design process saves thousands, if not millions, of dollars (Bergland and others, 1990:8). With CASE tools, engineers are given more freedom to try various

methods of problem analysis in a shorter period of time. Engineers can also implement requirements changes quicker and with less cost. An outcome of improved problem analysis is detailed and accurate software documentation.

During a 1987 IEEE Conference on Software Maintenance, a presenter was quoted as saying "... system and project documentation are crucial for high quality software development and maintenance" (Arthur and Krader, 1989:46). Proper software documentation improves accuracy and decreases changes due to programmer error. Electronic Design's Johna Till describes the tool AutoCode by saying "With the new version, updated documentation can be generated each time code is created" (Till, 1989:166). Every time an engineer changes code, the changes are automatically documented. The automated documentation keeps paperwork up-to-date and reduces the guessing about what was changed and why it was changed (Till, 1989:164). Improved documentation speeds the production of actual software code.

Labor involved in actual software coding is one of the highest expenses encountered in the development process. With the use of CASE tools, best case reductions of over 99 percent in coding time have been found. A U.S. Department of Justice attorney/advisor Lowell Denning estimates he spent between 25 and 50 hours developing an introductory screen without CASE tools. When he applied a CASE tool to the same task, he reduced the development time to under

10 minutes (Feil, 1989:57). Reductions in development time mean reductions in cost.

Air Force CASE Tool Evaluation Assistance

Many Air Force members are not aware of the valuable help available when it comes to evaluating the potential of perspective CASE tools. The Software Technology Support Center (STSC), located at Hill AFB, Utah, has the mission

> ... to assist Air Force Software Development and Support Activities (SDSAs) in the selection of technologies that improve the quality of their software products and increase the productivity of their efforts (Grotzky and others, 1991:1).

The STSC consolidates Air Force support for selection and evaluation of software environments, tools, and methods (Grotzky and others, 1991:1). Because individual agencies evaluate tools by different standards and do not share vital data, agency software professionals do not look at similar evaluations and thereby waste time and money. For these reasons, the STSC developed a standard strategy called the Test and Evaluation (T&E) Process to assist in consolidating the evaluation process.

> First, it gives software professionals the information required to make intelligent software tools selections. Second, it increases the comparability, consistency, and repeatability of software tool evaluations. Third, it improves the efficiency of the software tool evaluation process through the reuse of prior evaluation guidelines, procedures, and data. Fourth, it facilitates the feedback of customers requirements to software tool developers for future tool development (Grotzky and others, 1991:2).

Through this consolidation, all Air Force agencies can share the information gained to reduce the cost of developing and maintaining software and increase productivity.

In T&E process of the tool selection procedure, the STSC set up six phases: analysis, assessment, evaluation guidance, detailed evaluation, recommendation, and selection (Grotzky and others, 1991:2-3). This sequence narrows the field of tools being evaluated and improves the evaluation.

In the analysis phase, CASE tools available in one domain are identified and a Long List of Tools is generated. As a part of the analysis, characteristics (both quality and functional) for the domain in question are identified. Included in the identification are the Air Force essential characteristics of support of real-time activities and support of design teams (Grotzky and others, 1991:3, 16). The tool is then classified into its particular domain(s) (in this case, requirements analysis). Finally, a Short List of tools containing Air Force essential characteristics is generated. The analysis phase of the process is completed by STSC personnel with inputs from academia, Air Force agencies, and industry (Grotzky and others, 1991:3). As a part of the assessment phase, all of the identified characteristics are reviewed to ensure that all of the functional characteristics identified during analysis have been met by the candidate tool. This assessment is completed through a series of user interviews, informal

testing, documentation audits, and vendor surveys. Anyone can assess a tool using STSC guidance. In using this form of assessment, time and money can be saved. All assessments are combined to build a prioritized list used in the detailed evaluation phase (Grotzky and others, 1991:3).

The evaluation guidance phase activities consist of development of a test plan and characteristic evaluation guidelines. These are incorporated in the "domain Test and Evaluation Guideline (TEG)" (Grotzky and others, 1991:4). The guidance is a coordinated effort by the STSC with inputs from tool experts and users. The guidance put forth in TEGs is used in the detailed evaluation phase as the foundation for specific evaluation procedures (Grotzky and others, 1991:4).

Quality, performance, and functionality are validated during the detailed evaluation phase. A sample of the quality attributes reviewed are found in Table 2-1 on Page 2-8. The functional characteristics examined include:

> ...information capture, methodology support, model analysis, requirements tracing, data repository, documentation, data import/export, and reusability support (Grotzky and others, 1991:13).

Development of tool-specific Test and Evaluation Procedures (TEPs), executing the TEGs, recording results and updating the characteristics, and furnishing a final report are among the other activities performed in this phase. STSC-supervised evaluators accomplish the detailed review. The final report is compared to other reports during

recommendation and selection phases (Grotzky and others, 1991:4).

Table 2-1. Sample Software Quality Attributes Listing

Attributes	Tool	Products
Efficiency	*	
Integrity	*	
Reliability	*	
Survivability	*	
Usability	*	
Correctness		*
Maintainability		*
Verifiability		
Expandability		
Interoperability	*	
Reusability	*	
Transportability		

(Grotzky and others, 1991:14)

Strengths and weaknesses are highlighted in the evaluation phase. Activities include gathering customer-defined weighting criteria, assigning characteristic weight defaults, assessing the currency of the characteristic listings, calculating tool scores based on the weightings, adding the scores to the final reports, and producing a comparison report based on information from the preceding phases. This information is distributed at conferences, in

electronic media, tool reports, and in newsletters (Grotzky and others, 1991:4).

Identifying and comparing tools that meet the needs of a customer are produced in the selection phase. The final selection of a tool is the responsibility of the customer. The STSC is there as an advisor only.

As time has passed, the STSC has improved the T&G process. At the core of the STSC's assistance process is the Software Tool Evaluation Model (STEM) which includes:

a. Tool Domain
b. Tool Characteristics
    1) Air Force Essential Characteristics
    2) Default Weights
c. Test and Evaluation Guidelines (TEG) (Grotzky and others, 1991:6)

By using this model, the STSC and its customers can exchange information. The exchange allows the customer to make a better decision in tool selection and tool comparisons because of the improved knowledge base (Grotzky and others, 1991:6). Improved knowledge at little or no cost cannot be ignored.

United States Air Force Studies

The United States Air Force (USAF) has undertaken a limited number of CASE tool feasibility studies. These studies have been concentrated at a few strategic locations. The Standard Systems Center (SSC) at Gunter AFB AL and Rome Air Development Center (RADC) at Griffiss AFB NY are the

prime USAF locations for CASE tool initiatives. A review of the major efforts at these sites follows.

Standard Systems Center Efforts. The SSC is the USAF lead to provide an integrated CASE tool set. Within the past six months, a Request for Proposal (RFP) for the Integrated CASE (ICASE) tool set has been developed and is scheduled for release in October 1991. The contract, when awarded, is estimated to be worth as much as $25M. The RFP for ICASE requests an integrated CASE tool set be provided for Government use. The emphasis for the tool set is on usability. Contract award for the ICASE contract is scheduled for late 1991-early 1992 (Green, 1991:8).

Rome Air Development Center Efforts. RADC has a number of studies on CASE tool feasibility ongoing. One such study is the Requirements Engineering Testbed undertaken between July 1985 and February 1986 (Anonymous, 1988:9).

Requirements Engineering Testbed. The purpose of the study was "to define a ten-year research and development program for RADC's Requirements Engineering Testbed (RET)" (Anonymous, 1988:1). The primary goal behind the RET was to provide the means by which Air Force users could test and evaluate requirements for future systems. A secondary goal was to promote new tool use by industry, as well as the Air Force. RADC developed prototype tools for the user's beginning capability. The prototype also aided in the

understanding and investigation of requirements and their implications (Anonymous, 1988:1).

The problems which lead to the RET concept were uncovered in an RADC-sponsored survey of mission and acquisition specialists. From the survey, three major problem areas surfaced:

> (1) Requirements specifications were written for procurers (acquisition engineers) and their technical staffs. Thus mission users found them to be too technical and felt "shut out."
>
> (2) Mission users and contractors found it difficult to relate A-spec to B-spec (i.e. high-level system specification to software requirements) because of the significant "gulf" between them.
>
> (3) Contractors and mission users complained that traceability could only be demonstrated manually, making it hard to assess requirements coverage. (Anonymous, 1988:5-6)

RADC studies deemed RET as a potential solution to the problem. The complete RET model used two paths for optimal results. The first path was to evolve tools and methodologies like rapid prototyping for a quick benefit. Path two was to explore high-risk formal requirements language development (Anonymous, 1988:2).

The objective for the early testbed, in 1990, was to provide a number of requirements engineering capabilities via integrated tools. Meeting this objective would support the first path needed for optimization. The target, for 1995, is to provide the integrated capability via a formal

requirements language. Doing this is part of path two (Anonymous, 1988:17).

Work continues today to make the RET a viable step toward solving the requirements definition problems faced by the users and developers.

Direction of Future CASE Tool Development

With the creation of more and more CASE tools, the future looks promising for improved software development. Improved testing, industrialization of development, and growing productivity through CASE tools await the future software engineer.

Testing software will remain a difficult part of the development cycle. To aid in reducing the difficulties associated with testing, software developers need to look at test-generation needs early in the design process. CASE tools, such as T, are being used to automatically generate test scenarios during coding. By developing and performing the tests up front in the production process, the overall result will be higher quality, lower costing projects (Phillips, 1989:70-71).

Increased tool use should lead to an assembly line approach of software development. Software factories, using CASE tools, are being advocated as the future for software engineering. In 1985, the Japanese software community began the "Software Industrialized Generator and Maintenance Aids (SIGMA) project" (Akima and Ooi, 1989:13). This project

will establish a specialized environment for software engineering that will allow cheaper, faster, and larger software projects to be produced. Through the use of CASE tools, SIGMA will allow the mass production of software without the time and expense of previous efforts (Akima and Ooi, 1989:14). Industrialization allows for great repositories of software which provide greater software reuse possibilities. Also, the industrialization will make the production and combining of CASE tools cheaper and easier to use. Currently, as for any other new technology, CASE tools are expensive. Many companies make tools which are not readily compatible with another company's tools. So, having a CASE toolkit has been impossible. But not in the near future.

Increased productivity is another predicted outcome of the CASE tool revolution. The Datamation/Price Waterhouse opinion survey found the productivity prognosis bright over the next five years.

> Fifty-one percent of the organizations sampled predict that CASE would spawn software productivity jumps of up to 100% over the next five years. Productivity surges of up to 200% by 1999 are foreseen by the 20% of the CASE users surveyed. (Statland, 1989:33)

Productivity increases of this magnitude will make CASE tools a part of every software engineer's development process. Another forecast benefit of increased productivity is the faster production and longer life of software developed with CASE tools.

> Fifty-four percent of the current CASE customers expect to see much quicker software development by 1993, as a result of the technology. The most marked difference between today and tomorrow comes in the maintenance area. A whopping 45% of the companies predict that within five years, longer program life would be the big plus of using CASE tools. (Statland, 1989:33)

Speeding up the delivery of and improving the maintainability of new software would certainly reduce the lifecycle costs dramatically. A new day in software engineering is just around the corner.

Summary

CASE tools provide for improved software engineering now and in the future. Currently, well-established methods to manage the quality of the product are not beneficial enough. Besides CASE tools, a well-defined software engineering process must be in place for successful software development. This process must be understood and practiced by every member of the organization for quality and speed of CASE tools to be realized. "Our goal in applying new and existing technologies is to mechanize much of the front-end process and thus reduce development costs and improve product quality" (Bergland and others, 1990:7). Software is the future and improving its quality while reducing costs should be the objective of every software engineer.

> As CASE tools become more prevalent in software development, further research is required to answer how CASE will effect the products delivered to the end-user. The end-user should be able to understand whether using CASE will produce a higher quality software product, whether the

> product will be delivered in a timely manner, and most important whether the product will solve his business needs and contribute to the corporate strategy. (Batt, 1989:62)

No longer will customers tolerate the slow development of the past, the discovery of errors after delivery, and the unaffordable costs associated with software development today. Using CASE tools will reduce, if not eliminate, many of today's problems. Computer-Aided Software Engineering tools may not "be the silver bullet that will save the software industry," (Batt, 1989:2) But, when used with a well defined software engineering process, they are definitely a future gold mine, not a passing fad.

III. Methodology

Introduction

The hypothesis underlying the research is that CASE tool use during requirements analysis saves money and time by reducing deficiency and/or error correction in later stages of a project. Because data collection is vital to any causal research, justification, instrumentation, population and sample definitions, data collection plans, statistical tests, and limitations were established from the outset. A survey was determined to be the most appropriate manner for gathering the data inexpensively from a large population. A return of 50 percent of the surveys was considered to be sufficient to provide an appropriate amount of data for analysis (Emory, 1985:172-174). This chapter addresses the aforementioned concerns.

Justification

CASE tool use was and still is an emerging technology in software engineering. Only recently have CASE tool studies, of any significant quantity, been initiated. Of the published studies, the vast majority explored the commercial marketplace. Government CASE tool studies are virtually non-existent. The number of government agencies using tools is growing, but many agencies remain skeptical about CASE tools and their benefits. This research should bridge a portion of the believability gap.

Instrument

Surveying the population to obtain data was the most expeditious way in which to collect data without direct experimentation. Therefore, the survey instrument development was vital from the start.

The survey originally contained 29 pertinent and unbiased questions, all of which were designed to answer the research questions supporting the hypothesis. These questions were eventually pared down to 20 by eliminating redundancy and by combining related questions.

The questions were reviewed by AFIT/EN software engineering experts to ensure the questions were applicable for survey use. Before sending the surveys for approval, a validity check was performed to ensure that the survey instrument would not invalidate the conclusions drawn on the data collected. The questions and survey instrument were reviewed by the AFIT/EN advisor and members of the Graduate Software Systems Management Program at AFIT.

After instrument validation and advisor approval, the draft instrument, contained in Appendix A, was sent to AFIT/XP for approval. AFIT/XP then forwarded the survey package to the USAF Manpower and Personnel Center for approval. HQ AFMPC approved the survey with modifications on 20 May 91. The approval letter, outlining the changes, is contained in Appendix B. The final survey instrument contained 22 questions. The final survey package, including cover letter, the Privacy Act Statement, and the final

survey instrument, is presented in Appendix C.

Population/Sample

The population consists of United States Air Force agencies and the personnel in those organizations who develop software, along with a control group (selected from the same population) of personnel being trained to develop software using approved software engineering practices. The population was selected through information gathered from the General Services Administration's Federal Software Management Support Center's database of government CASE tool users, Air Force Communications Command's (AFCC) Computer Systems Division (CSD), and the United States Air Force (USAF) Software Technology Support Center (STSC). In this group, a point-of-contact was identified in the various agencies of the population. Through these points-of-contact, mail surveys were distributed, using a judgmental process, to persons managing software projects. These people tended to work with a given project over more than one phase of development and should have had a good perspective on the effects, or lack thereof, that CASE tools have had on a project.

The population, from which the sample and control groups were selected, was approximately 20,000 (varies due to changes in the development agencies). A sample size of 150 was determined to be adequate to obtain 67 responses. The 67 responses were required to have a confidence interval

of 90 per cent plus or minus 10 per cent. This was derived from the equation below:

$$n=\frac{n(z^2)p(1-p)}{(N-1)(d^2)+(z^2)p(1-p)}$$

where

n = sample size		
N = 20,000		(population size)
p = 0.5		(maximum sample size factor)
d = 0.1		(desired tolerance)
z = 1.645		(factor of assurance for 90 percent confidence interval)

A judgment sampling of the agencies was taken. The agencies surveyed include HQ Strategic Air Command, HQ Tactical Air Command and subordinate units to be determined by headquarters personnel, Air Force Communications Command (AFCC) CSD, AFCC Command and Control Systems Center, Air Force System Command's Aeronautical Systems Division, Air Force Logistics Command's Air Logistics Centers in San Antonio TX, Oklahoma City OK, and Sacramento CA, and Air Force Space Command's Space and Warning Systems Center.

The control group consisted of students from two resident Professional Continuing Education courses at AFIT. The two courses were WCSE 471 - Software Engineering Concepts and WCSE 472 - Specification of Software Systems. These courses teach the skills needed to properly develop requirements and software specifications. A knowledge of software engineering practices, including the use of CASE

tools, was assumed by the researcher. The students were surveyed on the first day of the class to minimize the bias of knowledge gained during the course of study. A total of six classes and 91 students were surveyed to develop the control group database.

Data Collection Plan

Data collection consisted of mail surveys. The mail survey focused on statistical data: costs, size, errors, etc. This data was analyzed according to strict statistical tests of categorical data. The tests include chi-squared distribution, contingency tables, and frequency distributions of the population and control group responses to assess any relationships or differences (Devore, 1987:556-591). Tests were set up with the assistance of AFIT/EN Math Department personnel. The results of the tests and the conclusions drawn from these tests were reviewed by AFIT/EN Math and Software personnel.

Statistical Tests

The statistical tests used to analyze the data included frequency distribution analysis, chi-square distributions, and contingency table comparison of the population and control groups. The actual tests performed are described in detail in Chapter 4.

Limitations

The survey was limited to Continental United States

(CONUS)-based USAF agencies only. Overseas USAF agencies were not considered due to their limited software development capabilities and missions. Limited time for survey and analysis of data forced the elimination of non-USAF agencies. Individual CASE tools were not identified nor reviewed for their usability.

Summary

Justifying efforts is a common practice in research. For the research presented in this thesis to succeed, defining the population, sample, and control size were critical. The researcher needed to know the what, how, when, and where of the data and the data collection process to develop useful questions and instrumentation. Using the appropriate statistical tests made the research defendable against scrutiny and review. The data analysis, including the equations used, is documented in Chapter 4.

IV. Data Analysis

Introduction

In this chapter, the focus is on making sense of the data gathered during the course of the research. To gain an understanding of the data, both the control group and sample data sets were statistically analyzed, singularly and in combination. Appendices D and F contain the raw data on the control and population samples, respectively. Appendices E, G, H, and I contain the statistical analyses results mentioned above. All analyses are based on meeting a 90 percent confidence interval.

Control Group Findings

Ninety-one cases were used in defining the control group. Not all survey respondents completed every question. The number of questions left unanswered caused the confidence in the data to fall below a 90 percent confidence level, making valid statistical analysis impractical. These questions will be discussed as required.

Frequency Distributions. By taking frequency distributions for each survey question, the validity of the data (meeting the 90 percent confidence interval criteria) can be assessed. Because respondents could provide more than one answer, questions 3, 9, and 18 are not analyzed with frequency distributions. Instead, the totals are displayed in table format.

Rank. Ninety of 91 respondents answered the question concerning rank. As Figure E-1 shows, a majority of the respondents fell into the 01 to 03 and CS-10 to GS-12 categories. This characteristic is consistent with the working levels of most Air Force units.

Programming Experience. In Figure E-2, 90 of 91 respondents answered the question concerning software programming experience. The respondents were normally distributed over the five categories. Three to 6 years of experience was the most common (at 30.8 percent) response.

Type of Systems Developed. Respondents could provide multiple answers about the type of systems developed in their offices, depending on the mission of their organization. 104 responses were obtained. Command and control, avionics, management information, and mission planning systems were the most widely developed software systems.

Table 4-1. Systems Under Development

No Response	6
Command and Control	20
Intelligence	5
Avionics	17
Management Information	14
Other Embedded/Real-Time	19
Other	23

Number of Systems Being Developed. Figure E-3 shows that 5 of the 91 respondents did not answer the question covering how systems their offices currently had under development. A majority (34.1 percent) of the surveyed offices develop 1 to 2 systems at present. Twenty-one of the offices are developing 10 or more systems. Seventeen offices have no systems development underway. These offices develop software policy, provide maintenance, or test software.

Cost of Systems Being Developed. As Figure E-4 shows, the clear majority of systems under development cost $1 million or more. One fact stood out in the answers concerning average cost of development: many people are not aware of the costs of systems their offices are developing.

System Lines of Code. Again, the responses held consistent with the vast majority of major systems development. As shown in Figure E-5, 33 percent of the systems being developed contained 100,000 or more lines of code.

Up until this point in the analysis, the results were used to provide an insight into the respondents' backgrounds, their organizations (in general), and system development activities. From this point on, the focus will be on CASE tool use by personnel and organizations.

CASE Tool Use by Organizations. Sixteen of the 91 people, compared in Figure E-6, surveyed did not respond as

to whether or not their organizations use CASE tools. Forty-one of 75 (54.7 percent) of the respondents answered that their organizations do not use CASE tools at all. Organizations that use CASE tools account for 45.3 percent of the total. The literature reviewed in Chapter 2 suggests that the author expected a higher percentage of offices that do not use CASE tools. This almost even split of use and non-use seems to indicate that either the Air Force is a leader in CASE tool use or that the control group offices selected were high in the number of CASE tool users. This divergence from published literature will be analyzed further when the comparison is made between the control group and the population sample later in this chapter.

Personal CASE Tool Users. Of 84 responses shown in Figure E-7, 62 or 73.8 percent do not use CASE tools at all. This fact is constant with the findings of the literature search.

Areas of CASE Tool Use. Again, respondents could provide more than one answer to the question concerning how their organizations used CASE tools in the software lifecycle. One hundred fifteen answers were given to the question. 33 percent or 38 people responded that their organization does not use CASE tools. Twenty-two answers appeared in the "Do not know" category. Of the organizations using CASE tools, requirements analysis and design, with 17 and 14 responses respectively, were the top

areas of use. This is steady with the findings of the literature reviewed. As Chapter 2 points out, lower CASE tools are just being developed for coding, testing, and maintenance. The upper CASE tools for requirements analysis and design are being used regularly by software development organizations (Bartow and Key, 1991:3-4). Twenty-three persons did not respond at all to the question. This number was not included in the 115 mentioned earlier in the paragraph.

Table 4-2. Areas of CASE Tool Use

No Response	23
Requirements Analysis	17
Design	14
Coding	8
Testing	9
Maintenance	7
None	38
Do Not Know	22

Requirements analysis garnered only 17 total responses. This low number indicates that the probability exists that CASE tool use for requirements analysis in the USAF is low, as was expected by the author.

Initial CASE Tool Cost. Figure E-8 shows the breakout of responses received concerning initial costs of

CASE tool use. Forty-three people, or 47.3 percent of the responses, indicated that the initial costs of CASE tool use were unknown. Only 13 respondents could provide a genuine categorical answer. Of the 15 responses in the $0-999 category, 12 answers could be traced back to where the respondents had signified that their organization did not use CASE tools. Also, the 20 "no" responses could be attributed to no organizational use of CASE tools.

Recurring CASE Tool Costs. The numbers and relationships described above are almost repeatable in this section. The distribution in Figure E-9 shows that of the 22 "no" responses and 17 "$0-999" category responses, all but 3 of the 39 were due to no organizational use of CASE tools. Four of the 12 persons who could identify initial cost categories did not know the recurring cost of CASE tool use. 48.4 percent, or 48, of the respondents did not answer for either because they lacked of knowledge or did not use CASE tools.

First Exposure to CASE Tools. Nineteen persons gave no response concerning their first exposure to CASE tools. The remaining 72 responses displayed in Figure E-10, broke out in this fashion: the majority learned from magazines/journals and the job, 23 and 21 respectively; 16 persons first learned of CASE tools in school; the remaining 12 persons were first introduced to CASE tools from other sources.

Areas Lacking Enough Data for Statistical Significance. As presented in Figures E-11 through E-19, a lack of response, indicated in the "no" response categories, by the control group made statistical evaluation of areas identified in Table 4-3 impractical. Respondents gave no response primarily because of organization non-use of CASE tools. Another reason for no answer was that the questions were ignored.

Table 4-3. Areas of Impractical Statistical Evaluation

CASE Tool Experience Levels
Requirements Analysis Errors/KLOC without CASE Tool Use
Total Error Percentage Attributable to Requirements Analysis without CASE Tool Use
Requirements Analysis Errors/KLOC with CASE Tool Use
Total Error Percentage Attributable to Requirements Analysis with CASE Tool Use
CASE Tool Use Increased Requirements Analysis Error Rates
CASE Tool Use Increased Productivity
CASE Tool Use Increased Development Costs
CASE Tool Use Increased Project Completion Time

Sample Group Findings

The sample group was defined by 67 total responses. Again, not all respondents completed every question. Questions which are statistically insignificant (well below a 90 percent confidence interval) are identified and the

implications discussed.

Frequency Distributions. As was the case with the control group, the sample group responses were reviewed through the use of frequency distribution charts. This review was undertaken to insure the validity of the data being analyzed and to gain an insight into the tendencies of the sample group.

Rank. All 67 respondents provided answers concerning rank. Figure G-1 shows that 37 (55.2 percent) of the respondents were in the 01-03 category. The concentration of the response is consistent with that of the control group.

Programming Experience. As with rank, responses were received from all 67 persons concerning their programming experience. Seventeen respondents had software experience levels of 10 or more years. 67.8 percent (46 persons) had at least 3 years experience. The distribution of responses in contained in Figure G-2.

Type of Systems Developed. Eighty responses were obtained to this multiple answer category. As Table 4-4 on the next page shows, management information and command and control systems were the systems found to be under development most often.

Number of Systems Being Developed. Figure G-3 indicates that all of the sample group answered the question pertaining to the number of systems under development. 55.2

Table 4-4. Systems Under Development

No response	5
Command and Control	19
Intelligence	10
Avionics	11
Management Information	22
Other Embedded/Real-Time	6
Other	7

percent of the respondents indicated that their office had 1 to 2 systems in development at the present time. 15 offices surveyed have no systems under development. Once again, these offices develop software policy, provide maintenance, or test software.

Cost of Systems Being Developed. As was the case with the control group, the cost of a majority of the systems under development in the sample group is over $1 million (19 responses). In Figure G-4, one can see that 13 persons marked that their costs are $0-999. This fact strongly suggests that two of the offices in the previous category do develop systems . However these offices are between development projects.

System Lines of Code. In the lines of code category, 66 of 67 persons responded with respect to system lines of code (LOC) for development projects. Although this is lower than the 90 percent confidence interval, meaningful

conclusions can be drawn from the data. Twenty-nine respondents, or 43.3 percent, indicated that their projects produced 10,000 to 99,999 LOC, as depicted in Figure G-5. This ranked first in this category as compared to the control group category where systems of over 1 million LOC were more prevalent.

As in the previous section, the preceding six paragraphs provided a background into the survey respondents. The remainder of this section is targeted at gaining an insight into CASE tool use in the sample group.

<u>CASE Tool Use By Organizations</u>. Figure G-6 exhibits the results of the survey responses on case tool use by organizations. As with the control group, the respondents in the sample group indicated that more than 50 percent of the surveyed organizations use CASE tools. Again this percentage was greater than my initial supposition had anticipated the percentage to be. The 52.2 percent of organizations that use CASE tools is even higher than the control group's 45.3 percent. The use of CASE tools in United States Air Force software development organizations is escalating or the offices surveyed had a higher CASE use rate as was indicated in the control group on page 4-4.

<u>Personal CASE Tool Use</u>. Of the 67 persons responding in this category (Figure G-7), 48 persons (71.6 percent) do not personally use CASE tools. This is consistent with the control group's 73.8 percent lack of

personal CASE tool use.

Areas of CASE Tool Use. The respondents could provide multiple answers pertaining to where their organizations used CASE tools in the software development lifecycle. A total of 139 answers were received in this category. 32 persons responded that their organization did not use CASE tools. 8 persons failed to answer the question and 6 did not know where CASE tools were used in their organizations. Of the remaining 21 respondents, they accounted for the 93 remaining answers in the category. Looking at this factor, one can find the indication that when an organization uses CASE tools, tools are used in more than one part of the software development lifecycle. The breakout of all responses in this category can be seen in Table 4-5 on the next page. Requirements analysis received only 16 responses in the sample group. From this total, it is clear that CASE tool use in the area of requirements analysis is low in the USAF.

First Exposure to CASE Tools. 63 of 67 survey respondents answered the question concerning their first exposure to CASE tools. Again, this level is less than the 90 percent confidence interval, but significant enough to provide a meaningful trend. Of the 63 responses in this category, job and school represented 67.1 percent (45 total) of the answers. This is different than the control group where job and magazines and journals took the majority

Table 4-5. Areas of CASE Tool Use

No Response	9
Requirements Analysis	16
Design	20
Coding	14
Testing	8
Maintenance	16
None	32
Do Not Know	6

responses were analyzed using frequency distribution charts. This combining of data allowed a better view of the software requirements/development population as a whole and opened to share. Figure G-10 presents the sample group responses.

Areas Lacking Enough Data for Statistical Significance. The number of respondents who failed to respond (tabulated under "no response") made a number of categories made statistical analysis meaningless. Figures G-8, G-9, and G-11 to G-19 exhibit the results of the survey responses. Table 4-6, on page 4-13, shows the categories where meaningful statistical analysis is unrealistic.

Combined Analysis of Groups

Frequency Distributions. Combining the control group and sample group data to look at the population as a whole is the purpose of this section of the chapter. 158 survey

Table 4-6. Areas of Impractical Statistical Evaluation

Initial Cost of CASE Tool Use
Recurring Cost of CASE Tool Use
Length Person Has Used CASE Tools
Requirements Analysis Errors/KLOC without CASE Tool Use
Total Error Percentage Attributable to Requirements Analysis without CASE Tool Use
Requirements Analysis Error/KLOC with CASE Tool Use
Total Error Percentage Attributable to Requirements Analysis with CASE Tool Use
CASE Tool Use Increased Requirements Analysis Error Rates
CASE Tool Use Increased Productivity
CASE Tool Use Increased Development Costs
CASE Tool Use Increased Project Completion Times

analysis, many areas in which it was previously impractical to do so. Questions 3, 9, and 18 will not be reviewed in this section because reviewing them would be repetitious. With this data combination, 17 of 19 areas of review can be analyzed to the needed population understanding.

Rank. As Figure G-1 shows, the 01 to 03 category was the area in which most respondents fell over any other category. Sixty-seven, or 42.4 percent, of the respondents were in this category. GS-10 to GS-12 was the second highest area of respondents with 29.7 percent (47 respondents) marking this category. With the majority of the respondents and the majority of Air Force software

personnel working levels in these two categories, it can be determined that the survey was distributed to the appropriate people. In the rank and grade data, no anomalies were found.

<u>Programming Experience</u>. In reviewing the experience data, the area of 3 to 6 years received the highest response rate. This is consistent with the experience levels of the categories focused on in the rank data and was consistent with the author's expected findings. In looking at Figure H-2, one can note the almost perfect normal distribution of the responses in the chart.

<u>Number of Systems Being Developed</u>. In a majority of the respondents' offices, there are only 1 to 2 systems being developed at survey completion time. In Figure H-3, one can notice that 68 responses were received in this area as compared to the next highest response area which was no systems under development. Only 33.5 percent of the respondents indicted that their organizations had 3 or more systems in development at the time of survey completion. The number of large software development organizations in the Air Force is not as high as the 50 percent the author anticipated during this effort.

<u>Cost of Systems Being Developed</u>. Ninety-one of the 158 responses (Figure H-4) indicated that the systems under development in their organizations had costs of over $100K. Of these 91, 61 persons marked that system costs

were $1M or more. With software costs being one of, if not, the most expensive portions of program development the statement in Chapter I concerning the fact that software cost DoD over $30 billion in the FY91 Budget is not out of line or realm of comprehension (Ferens, 1991:4).

Systems Lines of Code. The data, in Figure H-5, exhibits that the majority of systems under development during this survey had more than 10 KLOC. Forty-nine persons responded that their development systems had between 10,000 and 99,999 lines of code. Forty-six responses indicated that development systems contained more than 100,000 LOC. These numbers are consist with the current trends toward software project size.

As was the case with the group and sample sections, The previous six paragraphs have built a basis for understanding the population's makeup. This profile sets the general population as being at the company grade level or civilian equivalent, with 3 to 6 years experience in software programming, developing a variety of systems, normally develop 1 to 2 systems at one time, system costs are $100K or greater, and contain at least 10,000 LOC. The next 13 sections will build the population profile in regards to their use of CASE tools.

CASE Tool Use by Organizations. The Figure H-6 distribution of CASE tool use by organizations is almost even with non-users holding a slim 72 to 69 advantage. The

author, through reading, experience, and research, expected only 25 percent of the organizations to use CASE tools. This trend is considered significant because Air Force organizations are using or have the ability to use CASE tools in their software lifecycle.

Personal CASE Tool Users. The trend exhibited in Figure H-7 signifies that even though the organizations are using CASE tools, the individuals are not doing so. Sixty-nine percent (109 respondents) marked that they do not use CASE tools. This fact, in connection with the previous paragraph, lends credence to the assumption that organizations have the tools available but the people are not using them. Reasons for not using the tools could be: too difficult to learn or understand; being set in one's ways; afraid of using tools; no encouragement to use tools.

Initial CASE Tool Cost. Seventy-seven persons, or 48.7 percent, responded that they did not know the costs associated with the acquisition of CASE tools for their organizations. This high percentage, seen in Figure H-8, is indicative of the fact that the organizations surveyed either do not keep records of the costs or that the costs are not known throughout the organization.

Recurring CASE Tool Costs. As was the situation described in reference to initial cost, the same can be said about the recurring CASE tool costs. Figure H-9 portrays the identical responses and percentages for those persons

not knowing the costs. The reasons behind this trend are the same ones stated previously.

First Exposure to CASE Tools. The persons surveyed had a wide range of ways in which they were exposed to CASE tools. On the job garnered 45 responses while school and magazines and journals gained 37 and 34 responses respectively. Figure H-10 displays the data. Other sources were marked by 17 persons without any indications as to what those sources could be. With this information, one can extrapolate that CASE tools are becoming of increasing interest to the software community on the whole.

Experience with CASE Tools. When the control and sample groups were examined individually, this area of the survey could not be reviewed because of the number of no responses. However, by combining the data, an assessment of the population's experience using CASE tools can be inferred. With this data combination, Figure H-11 presents the fact that experience levels for those surveyed is less than 1 year. This factor is a result of the newness of CASE tool technology.

Errors Attributable to Requirements Analysis without CASE Tool Use. In this area, the 158 respondents had a wide range of answers. But as shown in Figure H-12, no response answers lead the pack with 82 (51.9 percent) total. A majority of the no response answers are tracked to organizations that do not use CASE tools. Of the remaining

responses, 31 persons indicated that less than 10 errors/KLOC were traceable to requirements analysis (RA), 20 indicated that 10 to 25 errors/KLOC were traceable to RA, 12 indicated that 26 to 50 errors/KLOC traceable to RA, 10 indicated that 51 to 100 errors/KLOC traceable to RA, and 3 indicated that over 100 errors/KLOC were traceable to RA. Many comments from respondents indicated that their organizations do not track errors to specific areas. These comments demonstrate that Air Force software development organizations need to track errors closer to find trends and begin to eliminate problem areas.

Percentage of Total Errors Credited to Requirements Analysis. As in the previous data set, no responses from organizations not using CASE tools took the majority share of responses. In Figure H-13, the percentage of total errors credited to requirements analysis varied form less than 5 percent to over 50 percent. This data set suffers the same lack of error tracking problems that the previous data set encountered.

In the next four paragraphs, insights into the population's views of CASE tools were examined. The opinions of the population surveyed can be expanded to the entire Ar Force software development arena.

Errors Increased While Using CASE Tools. Excluding the 78 "no" responses, the majority of the answers (33 total) indicate that the population neither agree or

disagrees that error rates increased when CASE tools were used in software development. Forty-three persons responded that they either disagreed or strongly disagreed with the statement as seen in Figure H-16. These disagreement leads to the conclusion that the population understands the purpose of CASE tools.

Productivity Increased Using CASE Tools. Forty persons responded that they agreed or strongly agreed that CASE tools increased productivity. Another 40 had no opinion one way or another concerning the statement. In Figure H-17, 76 answers are shown to have been no responses.

Development Costs Increased Using CASE Tools. Figure H-18 displays the breakout of answers in this area of analysis. Seventy-nine "no" responses can be found. Twenty-five persons indicated they disagreed with the statement. However, 52 persons indicated that they agree or had no opinion that overall development costs increased using CASE tools. This is opposite of the intended purpose of CASE tools to lower development costs. Many respondents did comment that their opinions were based on the first or only project completed in their organization to use CASE tools.

Project Completion Time Increased Using CASE Tools. The opposite of the intended purpose of CASE tools is displayed in this area of inquiry. In Figure H-19, "no" responses tallied 79, disagreed tallied 33, and 44 agreed or

had no opinion that using CASE tools increased project completion time. CASE tools are designed to reduce the time needed to complete projects. A number of respondents stated that the increased completion time was a result of learning to use the tools or not knowing how to use the tools at all. With the result in the last two areas, it is clear that more education is needed into the purpose of CASE tools.

Areas Still Lacking Enough Data for Statistical Significance. The areas of errors/KLOC while using CASE tools and percentage of total errors credited to requirements analysis using CASE tools, even after combination of data from the two groups, did not have enough data to be analyzed. The lack of response resulted from a lack of data tracked in these areas, newness of CASE tools to organizations, and non-tool use.

Contingency Tables and Chi-Square Calculations. The contingency tables and Chi-Square calculations completed in Appendix I are explained in this section. The tables and calculations were completed using the SAS Statistical program on the AFIT computer cluster. The conclusions drawn from these statistics were confirmed with AFIT/EN statistical experts. The formula and reasoning behind the Chi-Square is as follows:

$$\chi^2=\sum\sum_{j}\left[\frac{(n_{ij}-E_{ij})^2}{E_{ij}}\right]$$

Null hypothesis: The two variables are independent.

Alternative hypothesis: The two variables are dependent.

Rejection region: Reject H_0 if Chi-Square exceeds the tabulated critical value for a equals alpha and df =(r-1)(c-1), where

r = number of rows in the table

c = the number of columns in the table (Ott, 1977:294-298).

The definition for independence is:

> Two variables that have been categorized in a two-way table are independent if the probability that a measurement is classified into a given cell of the table is equal to the probability of being classified into that column. This must be true for all cells of the table (Ott, 1977:295)

Independent is stating that the two groups are not related in any way. Dependent is just the opposite; the control and sample groups are related. Cells are possible responses. The observed and expected cell counts and calculations for each data source are contained in Appendix I, Tables I-1 through I-19.

Programming Experience. The Chi-Square value calculated for experience was 4.935. This number is less than the critical value of 9.23635. Therefore, we accept the null hypothesis that the control and sample groups are independent.

Cost of Systems Being Developed. The Chi-Square value is 26.415. Since this is greater than the critical value of 9.23635, we reject the null hypothesis and

determine that the control and sample groups are dependent. The cell values, or observations, have to much variance too to be acceptable.

System Lines of Code. The Chi-Square value of 14.856 is greater than the critical value of 9.23635. Therefore, we reject the null hypothesis and can determine that the control and sample groups are dependent.

CASE Tool Use by Organizations. The critical value of 4.60517 is less than the Chi-Square value of 13.797. The null hypothesis is rejected and the control and sample groups are deemed to be dependent.

Personal CASE Tool Use. The values for the critical and Chi-Square numbers are the same as the organizational data. Therefore, the same conclusions and reasoning applies to this data.

First Exposure to CASE Tools. The Chi-Square value for this data is 13.027. This exceeds the critical value of 7.77944. The null hypothesis is rejected and the control and sample groups are determined to be dependent.

Percentage of Errors Credited to Requirements Analysis without CASE Tools. The critical value of 9.23635 is exceeded by the Chi-Square value of 23.499. Therefore, the cell counts vary too much to be accurate and the null hypothesis is rejected. Thus the control and sample groups are dependent.

Areas of Uncertainty. The 11 areas not discussed

above had problems in the application of the Chi-Square distribution. In all cases, cell counts less than 5 in at least 30 percent of the cells made the validity of the Chi-Square calculations questionable.

Summary

A great deal of data was collected and analyzed during the course of this work. In many cases, the data lacked the necessary numbers for a good insight into the population. Answers were missing in many categories. On the whole, however, the data did give us enough information to determine if we can answer the research questions listed in Chapter I. Chapter V will provide those answers and make the conclusions and recommendations that have occurred as a result of this research.

V. Conclusions and Recommendations

Introduction

This chapter wraps up the research into CASE tool use in requirements analysis reducing software errors associated with requirements analysis. Conclusions and answers to the research questions, along with recommendations for future research into this area, are provided.

Conclusions

Research Question #1. The question was: What percentage of DoD software developers use CASE tools during the requirements analysis phase of project development? What percentage do not use CASE tools?

The data analyzed in Chapter IV indicates that the majority of software developers do not use CASE tools in the requirements analysis phase of project development. This is consistent with the findings in the literature review. The Air Force is just beginning to enter the CASE tool arena in the requirements analysis area. Within the next 10 years, one should see a dramatic increase in the number of CASE tools users in all phases of software development; not just requirements analysis.

Research Question #2. The question was: For what reasons did agencies choose to use CASE tools or not to use CASE tools?

The data reviewed indicated that the population was still uncertain of using CASE tools. Many organizations did not use the tools because of the expense involved, the lack of understanding into how the tools worked or could help, lack of training of personnel, or the total rejection of the CASE tool ideas. Education into the benefits of CASE tools is needed throughout the Air Force. The Software Engineering Professional Continuing Education is a leading effort in the education and more efforts like this are needed to increase the CASE tool awareness of software developers.

Research Question #3. The question was: What was the project size (lines of code, Cost)? Was project size a factor in deciding whether or not to use CASE tools on the Project?

The data analyzed portrayed that most software development projects are of a significant size. This coupled with the organizational and personal CASE tool use levels leads one to conclude that the size of a project was not a factor in determining whether or not to use CASE tools. Personal or organizational preferences tend to be the driving factor on CASE tool use.

Research Question #4. The question was: What were the initial costs of using the tools? Follow-on or recurring costs?

Not knowing the data was the significant finding in this area. Organizations that use CASE tools do not routinely track the costs of using the tools or do not give the information out to everyone in the organization. A better way of obtaining the data for future research efforts must be found. Whether the budget offices are surveyed or the data is requested in a different manner is up to future researchers.

Research Question #5. The question was: What cost savings were found by using CASE tools over not using CASE tools (including the recovery of the initial costs)?

The conclusions drawn in this area are simple. Not enough data is being tracked to make any assertions one way or another in regards to costs. With the tightening of the budget expected over the next few years, organizations need to find areas in which they can track costs in order to reduce them. Tracking of the costs of errors and the phase of development in which they occurred will enable managers to better understand where problem areas are. Knowing where the problems are is the first step in reducing the costs of errors.

Research Question #6. The question was: What errors were found? When? Did using CASE tools reduce the number of errors?

The results in this area are the same as the results

for research question #5. Not enough data is being tracked to ascertain any significant findings in this area. The opinion of the population is one that using CASE tools will reduce errors, but so far the opinions have not been heeded or acted upon.

Overall Conclusions

The software development organizations throughout the Air Force are just getting on the CASE tool bandwagon. The effects of CASE tools on projects has yet to be realized. Efforts are underway to increase the use and awareness of CASE tools. The upcoming release of the ICASE request for proposal is a giant step toward getting CASE tools into the hands of the developers. These integrated tools will enable the developers to engineer projects with greater ease and accuracy. These factors should manifest an overall savings in time and money needed to develop and maintain software. The Air Force Institute of Technology's Software Engineering Professional Continuing Education program provides developers the opportunity to learn the current methods and practices of the ever-changing, ever-growing profession of software engineering. By keeping up with the changes in the software world, costs can be saved and even avoided.

Recommendations for Future Research

An enormous amount of possible research endeavors in the area of CASE tools remain. With the Air Force just

releasing the RFP for an integrated CASE tool set, the case study possibilities are numerous. Also, there are possibilities for a more detailed analysis of the Air Force as a whole using descriptive statistics.

The case study approach has two immediate possibilities. First, review of a completed software project, where CASE tools were used in a part of the development, can be undertaken. This study could provide insight into the effectiveness of early CASE tools, how and where they were used, and lessons learned by the developing organization. Second, tracking a new system being developed using the new ICASE toolkit is a long range project. This study could provide feedback to the practicality of the ICASE product and its implementation.

In completing a more detailed analysis of the Air Force, one would need to build a much more thorough survey instrument to obtain the required exacting data. By collecting this type of data, more precise quantitative statistics can be derived. With greater precision, one can draw more specific conclusions about the Air Force population as a whole and as various subgroups.

Summary

The thesis was undertaken in an effort to try and provide insight and understanding into the current use of CASE tools in the requirements analysis phase of software

development. Expectations were ones that the Air Force did not have great efforts into this area of tool use, that data tracking in these areas was lacking, and that improvements were needed in all areas related to CASE tools. The findings of the research supported the expectations of the author. Much work still remains in the CASE tool arena. In fact, the work is only beginning. CASE tools can and will make tremendous differences in future software development projects or efforts.

Appendix A: Initial Survey Package

Survey Approval Request

This appendix contains the information sent to HQ AFMPC to request approval to distribute a survey.

Request Form

REQUEST FOR APPROVAL OF SURVEY

AFIT/GSS/ENG/91D-7
Capt M. B. Key, Jr.

1. TITLE OF PLANNED SURVEY.

   Computer-Aided Software Engineering (CASE) Tool Use Survey

2. NAME AND ADDRESS OF INDIVIDUAL REQUESTING APPROVAL.

   AFIT Survey Control Officer

   AFIT/XP
   Capt Frisco-Foy (DSN 785-4219)
   Wright-Patterson AFB 45433-6583

3. STATEMENT OF SURVEY PROBLEM, SURVEY PURPOSE, PREFERRED ADMINISTRATION TIME FRAME, AND JUSTIFICATION.

   a. SURVEY PROBLEM.

      Software projects have become enormous and extremely complex. To assist the future software engineer in managing this growing complexity, today's engineers are creating automated tools to simplify the software management and development process. These products are called Computer-Aided Software Engineering (CASE) tools. To be effective, CASE tools must be used from the beginning of the software development process. No research has been conducted to determine the impacts of using these tools during requirements analysis for Air Force software development projects.

   b. SURVEY PURPOSE.

      The intent of this questionnaire is to gather sufficient data to determine whether using CASE

tools during requirements analysis reduces errors in the overall development cycle and, ultimately, save money.

c. PREFERRED ADMINISTRATION TIME FRAME.

As soon as practical. Survey data must be collected by 10 July 1990 for meaningful analysis.

d. JUSTIFICATION FOR SURVEY.

The information collected will aid in the analysis of CASE tools use during requirements analysis in the Air Force. This research effort is also a requirement of the Master of Science thesis at the Air Force Institute of Technology.

4. HYPOTHESIS TO BE TESTED BY THE SURVEY.

CASE tool use during requirements analysis correlates directly to a reduction of errors attributable to poor requirements analysis resulting in a reduction of deficiency and/or error corrections in later stages of a project.

5. POPULATION TO BE SURVEYED.

a. DESCRIPTION OF POPULATION TO INCLUDE MILITARY AND CIVILIAN EMPLOYMENT STATUS AND BY WHOM EMPLOYED.

Software project managers and programmers (of all ranks and grades) at all CONUS USAF software development organizations.

b. SIZE OF POPULATION.

Approximately 20,000.

6. DESCRIPTION AND SIZE OF SAMPLE SELECTED.

a. SAMPLE DESCRIPTION.

The sample will consist of individuals (both military and civilian) who work directly on USAF software development projects.

b. SIZE OF SAMPLE AND IF INDIVIDUAL RESPONDEES ARE KNOWN OR NOT KNOWN.

Sample size will be 600. The names of the individual respondents are unknown.

7. METHOD OF SELECTION OF THE SAMPLE.

Simple random sample.

8. METHOD OF CONDUCTING THE SURVEY.

Questionnaires will be distributed to subjects through their parent organization. Completed questionnaires will be individually return mailed.

9. DESCRIPTION OF THE STATISTICAL ANALYSIS PLAN OR OTHER METHOD OF EVALUATION.

Analysis of variances, testing of means, correlation of populations, and basic averages and percentages.

10. METHOD OF TABULATING SURVEY RESULTS.

Computer tabulation of answer sheets and manual coding of write-in responses into categories and histogram analysis and reporting.

11. USE AND DISPOSITION OF RESULTS.

The survey results will be basic inputs to a published Air Force Institute of Technology, School of Systems and Logistics, student thesis. The results may be released to the public and the Air Force Human Resources Laboratory in compliance with AFR 12-30.

12. COMMAND APPROVAL CONTACT POINT.

Capt Brad Ayers
Hq AFCC/PGSS
Scott AFB Il
DSN 576-3642

13. Copy of the proposed survey questionnaire, including Privacy Act Statement, is attached.

Survey Cover Letter

LSG (Capt Key, DSN 785-8989)

CASE Tool Use Survey

USAF Software Managers and Developers

1. Please take the time to complete the attached questionnaire.

2. The survey measures Computer-Aided Software Engineering (CASE) tool use during the requirements analysis activities of software development in USAF software development agencies. The data gathered will become part of an AFIT research project and may influence approaches to requirements analysis in future software projects. Your individual responses will be combined with others and will not be attributed to you personally.

3. Your participation is completely voluntary, but we certainly appreciate your help. For further information, contact Lt Col Lawlis at DSN 785-6027 or Capt Key at DSN 785-8989.

JOHN W. SHISHOFF, Lt Col, USAF
Director, Graduate Programs
School of Systems and Logistics

4 Atch
1. Privacy Act Statement
2. Questionnaire
3. Computer Answer Sheet
4. Return Envelope

Privacy Act Form

PRIVACY ACT STATEMENT

In accordance with paragraph 8, AFR 12-35, the following information is provided as required by the Privacy Act of 1974:

a. Authority

(1) 10 U.S.C. 301, Departmental Regulations; and/or

(2) 10 U.S.C. 8012, Secretary of the Air Force, Powers, Duties, Delegation by Compensation; and/or

(3) EO 9397, 22 Nov 43, Numbering System for Federal Accounts Relating to Individual Persons; and/or

(4) DOD Instruction 1100.13, 17 Apr 68, Surveys of Department of Defense Personnel; and/or

(5) AFR 30-23, 22 Sep 76, Air Force Personnel Survey Program.

b. Principal Purposes. The survey is being conducted to collect information to be used in research aimed at illuminating and providing inputs to the solution of problems of interest to the Air Force and/or DOD.

c. Routine Uses. The survey data will be converted to information for use in research of management related problems. Results of the research, based on the data provided, will be included in written master's theses and may also be included in published articles, reports, or texts. Distribution of the results of the research, based on the survey data, whether in written form or presented orally, will be unlimited.

d. Participation in this survey is entirely voluntary.

e. No adverse action of any kind may be taken against any individual who elects not to participate in any or all of this survey.

Proposed Survey Instrument

Computer-Aided Software Engineering (CASE) Tool Use Survey

It is estimated that the United States Air Force (USAF) encountered $30 billion in software-related costs in FY 1990. Of this amount, software development and maintenance accounted for about 80% of the total estimate. Cheaper and more efficient ways of working with software must be developed and used in order to reduce the skyrocketing development and maintenance expenditures.

CASE tools for requirements analysis are an important part of the CASE family. CASE tool use can improve the accuracy and traceability of requirements throughout the software development lifecycle. A proper requirements analysis can save thousands, if not millions of dollars annually.

This survey is being sent to all CONUS USAF software development organizations. The survey is also being given to Professional Continuing Education students who attend courses at the Air Force Institute of Technology. Please answer the questions based on your organization and the programs that you are responsible for.

Any comments, suggestions, and explanations are welcomed and encouraged. All inputs will be considered in the final report. Address all inquiries to Capt Marvin Key, AFIT/LSG, Wright-Patterson AFB OH 45433 (DSN 785-8989).

Survey Completion

This survey contains 20 questions. For questions 1-16, circle the appropriate answer. For questions 17-20, write your answer after each question. Accompanying the survey, you will find a computer answer sheet. Please mark your answers on the computer answer sheet after completing the survey.

1. What is your rank?

a. Enlisted
b. 01 to 03
c. 04 to 06
d. 07 to 10
e. Below GS-10
f. GS-10 to GS-12
g. GS/GM-13 to GS/GM-15
h. Above GS/GM-15

2. How many years of software programming experience do you have?

a. Less than 1 year
b. 1 to 3 years
c. 3 to 6 years
d. 6 to 10 years
e. More than 10 years

3. What kind of systems does your office develop?

a. Command and control
b. Intelligence
c. Avionics
d. Mgmt Information
e. Other embedded/real-time (__________)
f. Other (Please specify ______________)

4. How many systems does your organization have in development at the present time?

a. 0 b. 1 to 2 c. 3 to 5 d. 6 to 9 e. 10 or more

5. What is the average cost of a system under development in your organization?

a. $0 to 9,999
b. $10,000 to 49,999
c. $50,000 to 99,999
d. $100,000 to 999,999
e. $1,000,000 or more

6. What is the average software project size you develop (in lines of code)?

a. Less than 500
b. 500 to 999
c. 1,000 to 9,999
d. 10,000 to 99,999
e. More than 100,000

7. In what areas (mark all) of the software lifecycle are CASE tools used in your office?

a. Requirements analysis
b. Design
c. Coding
d. Testing
e. Maintenance
f. None
g. Do not know

8. What was the initial cost of using CASE tools (include purchase price, any special hardware and initial training costs)?

a. $0 to 999
b. $1,000 to 9,999
c. $10,000 to 49,999
d. $50,000 to 99,999
e. $100,000 or more (Please specify _____________)

9. What are your annual recurring costs?

a. $0 to 999
b. $1,000 to 4,999
c. $5,000 to 9,999
d. $10,000 to 49,999
e. $50,000 or more (Please specify____________)

10. Where were you first exposed to CASE tools?

a. On the job b. In school c. Magazines or journals d. Other (Please specify ___________________)

11. How long has your organization been using CASE tools?

a. Less than 1 year b. 1 to 2 years c. 3 to 4 years d. More than 4 years

12. On your projects that do/did **NOT** use CASE tools, how many errors per thousand lines of code (KLOC) can be traced back to problems with requirements analysis (please provide as accurate a number as possible)?

a. Less than 10 errors/KLOC
b. 10 to 25 errors/KLOC
c. 26 to 50 errors/KLOC
d. 51 to 100 errors/KLOC
e. More than 100 errors/KLOC (Please specify ________)

13. What percentage of total errors did requirements definition error account for in the projects listed above?

a. Less than 5%
b. 5 to 10%
c. 10 to 25%
d. 25 to 50%
e. More than 50% (Please specify________________)

14. On your projects that do/did use CASE tools, How many errors per thousand lines of code can be traced back to problems with requirements analysis (please provide as accurate a number as possible for each project)?

a. Less than 10 errors/KLOC
b. 10 to 25 errors/KLOC
c. 26 to 50 errors/KLOC
d. 51 to 100 errors/KLOC
e. More than 100 errors/KLOC (Please specify ________)

15. What percentage of total errors did requirements definition error account for in the projects listed above?

a. Less than 5%
b. 5 to 10%
c. 10 to 25%
d. 25 to 50%
e. More than 50% (Please specify________________)

16. If used, why were CASE tools selected to be used for requirements analysis?

a. Tools made task easier
b. Analysis more accurate
c. Directed to use tools
d. Done as a test case
e. Not used
f. Other (Please specify____________________)

Respond to the next four statements using the following scale:

Strongly disagree	Disagree	Neither	Agree	Strongly agree
A	B	C	D	E

17. Errors increased after using CASE tools.

18. Productivity increased when using CASE tools.

19. By using CASE tools, overall development costs increased.

20. Using CASE tools, time to complete the projects increased.

Appendix B: Air Force Manpower and Personnel Center Response

AFMPC/DPMYOS Letter, 20 May 91

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE MILITARY PERSONNEL CENTER
RANDOLPH AIR FORCE BASE TX 78150-6001

REPLY TO ATTN OF: DPMYOS

20 MAY 1991

SUBJECT: Survey Approval (Your Ltr, 1 May 1991)

TO: AFIT/XPX

1. Capt Key's survey, "Computer-Aided Software Engineering (CASE) Tool Use," is approved, contingent upon the changes listed below. The Survey Control Number (USAF SCN) 91-32, and the expiration date of 30 September 1991 must appear on the cover of the survey. Please have Capt Key forward a copy of the corrected survey to this office prior to administration.

2. The major changes apply to the population definition, sample selection, and scope of the survey. The defined population needs to be much more select in order to get a sample of personnel who might conceivably know what CASE tools are and who may have used them. The sample required for a 90%±10 confidence interval, the allowable interval for thesis students, is 67 for any population over 6041. Capt key is authorized to survey 150 people. The scope of the survey as currently written, i.e., from an organizational perspective, would probably only be known by very senior managers. Therefore, most of the rewording of the questions is to help the individual relate their own experience to CASE tools. Capt Key also needs to have very specific instructions to the offices distributing the surveys in order to get a meaningful sample.

3. Changes to the survey instrument are:

a. In the cover letter, take out the instruction to include name, rank, etc., on the answer sheet.

b. On the general instruction page, take out the first two paragraphs. The survey respondent doesn't require this information in order to complete the survey. Also, the respondent should be instructed to complete the survey using the answer sheet. To complete the survey and then transfer responses to the answer sheet is not necessary.

c. On question 1, delete option 'd' because we do not recommend surveying general officers. Also, enlisted personnel may take offense at only having one response option. Recommend grade group (E1-E3, E4-E6, E7-E9) options be used for enlisted personnel.

d. On question 4, change stem to read, "How many systems are you developing at the present time?"

e. On question 5, change the stem to read, "What is the average cost of systems you develop?"

f. On question 6, change the stem to read, "What is the average software project size you develop?"

g. After question 6, add two questions:

(1.) Does your organization use CASE tools? A. Yes B. No

(2.) Do you use CASE tools? A. Yes B. No

h. On question 7, change the stem to read, "In what areas of the software lifecycle do you use CASE tools?"

i. On questions 8 and 9, add response options for "I don't know."

j. On question 11, change stem to read, "How long have you been using CASE tools?"

k. On questions 12 and 14, insert the word "your" prior to the word "projects."

l. At the end of the survey, tell the respondents how to return the survey.

4. If Capt Key has any questions about this review or the required changes, he may contact Capt Burgess at DSN 487-5680. Again, please have Capt Key send us a copy of the final survey prior to administration.

Charles H. Hamilton

CHARLES H. HAMILTION, GM-13
Chief, Personnel Survey Branch

After reviewing the comments and suggests from AFMPC/DPMYOS, changes were made to the original survey instrument. The final instrument is included in Appendix C.

Appendix C: Final Survey Package

Cover Letter

LSG (Capt Key, DSN 785-8989)

CASE Tool Use Survey

USAF Software Managers and Developers

1. Please take the time to complete the attached questionnaire.

2. Persons completing the questionnaire should be in a position of managing one or more software development projects, managing a subsystem of a larger project, or developing specifications and code. The project can be an in-house development or a contracted effort. All development efforts will be considered. Also, all experience levels will be covered by the survey instrument.

3. The survey measures Computer-Aided Software Engineering (CASE) tool use during the requirements analysis activities of software development in USAF software development agencies. The data gathered will become part of an AFIT research project and may influence approaches to requirements analysis in future software projects. Your individual responses will be combined with others and will not be attributed to you personally.

4. Your participation is completely voluntary, but we certainly appreciate your help. For further information, contact Lt Col Lawlis at DSN 785-6027 or Capt Key at DSN 785-8989.

JOHN W. SHISHOFF, Lt Col, USAF
Director, Graduate Programs
School of Systems and Logistics

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1. Privacy Act Statement
2. Questionnaire
3. Computer Answer Sheet
4. Return Envelope

Privacy Act Statement

PRIVACY ACT STATEMENT

In accordance with paragraph 8, AFR 12-35, the following information is provided as required by the Privacy Act of 1974:

a. Authority

(1) 10 U.S.C. 301, Departmental Regulations; and/or

(2) 10 U.S.C. 8012, Secretary of the Air Force, Powers, Duties, Delegation by Compensation; and/or

(3) EO 9397, 22 Nov 43, Numbering System for Federal Accounts Relating to Individual Persons; and/or

(4) DOD Instruction 1100.13, 17 Apr 68, Surveys of Department of Defense Personnel; and/or

(5) AFR 30-23, 22 Sep 76, Air Force Personnel Survey Program.

b. Principal Purposes. The survey is being conducted to collect information to be used in research aimed at illuminating and providing inputs to the solution of problems of interest to the Air Force and/or DOD.

c. Routine Uses. The survey data will be converted to information for use in research of management related problems. Results of the research, based on the data provided, will be included in written master's theses and may also be included in published articles, reports, or texts. Distribution of the results of the research, based on the survey data, whether in written form or presented orally, will be unlimited.

d. Participation in this survey is entirely voluntary.

e. No adverse action of any kind may be taken against any individual who elects not to participate in any or all of this survey.

Final Survey Instrument

Computer-Aided Software Engineering (CASE) Tool Use Survey

This survey is being sent to all CONUS USAF software development organizations. The survey is also being given to Professional Continuing Education students who attend courses at the Air Force Institute of Technology. Please answer the questions based on your organization and the programs that you are responsible for.

Any comments, suggestions, and explanations are welcomed and encouraged. All inputs will be considered in the final report. Address all inquiries to Capt Marvin Key, AFIT/LSG, Wright-Patterson AFB OH 45433 (DSN 785-8989).

Survey Completion

This survey contains 22 questions. For questions 1-18, circle the appropriate answer. For questions 19-22, write your answer for each question in the blank preceding each question. Accompanying the survey, you will find a computer answer sheet. Please write your computer answer sheet number in the space provided after the last question (the number can be found on the lower right hand corner of the front page of the answer sheet). Then, using a #2 pencil, please mark your answers on the computer answer sheet

If you have any comments, please include them in the space provided after the Computer Answer Sheet number on page 4 of the questionnaire.

1. What is your rank?

a. E1 to E3
b. E4 to E6
c. E7 to E9
d. 01 to 03
e. 04 to 06
f. Below GS-10
g. GS-10 to GS-12
h. GS/GM-13 to GS/GM-15
i. Above GS/GM-15

2. How many years of software programming experience do you have?

a. Less than 1 year
b. 1 to 3 years
c. 3 to 6 years
d. 6 to 10 years
e. More than 10 years

3. What kind of systems does your office develop?

a. Command and control
b. Intelligence
c. Avionics
d. Mgmt Information
e. Other embedded/real-time (________)
f. Other (Please specify ____________)

4. How many systems are you developing at the present time?

a. 0
b. 1 to 2
c. 3 to 5
d. 6 to 9
e. 10 or more

5. What is the average cost of systems you develop?

a. $0 to 9,999
b. $10,000 to 49,999
c. $50,000 to 99,999
d. $100,000 to 999,999
e. $1,000,000 or more

6. What is the average software project size you develop (in lines of code)?

a. Less than 500
b. 500 to 999
c. 1,000 to 9,999
d. 10,000 to 99,999
e. More than 100,000

7. Does your organization use CASE tools?

a. Yes
b. No

8. Do you use CASE tools?

a. Yes
b. No

9. In what areas of the software lifecycle do you use CASE tools (mark all)?

a. Requirements analysis
b. Design
c. Coding
d. Testing
e. Maintenance
f. None
g. Do not know

10. What was the initial cost of using CASE tools (include purchase price, any special hardware and initial training costs)?

a. $0 to 999
b. $1,000 to 9,999
c. $10,000 to 49,999
d. $50,000 to 99,999
e. $100,000 or more (Please specify ________________)
f. Do not know

11. What are your annual recurring costs?

a. $0 to 999
b. $1,000 to 4,999
c. $5,000 to 9,999
d. $10,000 to 49,999
e. $50,000 or more (Please specify________________)
f. Do not know

12. Where were you first exposed to CASE tools?

a. On the job b. In school c. Magazines or journals d. Other (Please specify ________________)

13. How long have you been using CASE tools?

a. Less than 1 year b. 1 to 2 years c. 3 to 4 years d. More than 4 years

14. On your projects that do/did **NOT** use CASE tools, how many errors per thousand lines of code (KLOC) can be traced back to problems with requirements analysis (please provide as accurate a number as possible)?

a. Less than 10 errors/KLOC
b. 10 to 25 errors/KLOC
c. 26 to 50 errors/KLOC
d. 51 to 100 errors/KLOC
e. More than 100 errors/KLOC (Please specify ________)

15. What percentage of total errors did requirements definition error account for in the projects listed above?

a. Less than 5%
b. 5 to 10%
c. 10 to 25%
d. 25 to 50%
e. More than 50% (Please specify________________)

16. On your projects that do/did use CASE tools, How many errors per thousand lines of code can be traced back to problems with requirements analysis (please provide as accurate a number as possible for each project)?

a. Less than 10 errors/KLOC
b. 10 to 25 errors/KLOC
c. 26 to 50 errors/KLOC
d. 51 to 100 errors/KLOC
e. More than 100 errors/KLOC (Please specify ________)

17. What percentage of total errors did requirements definition error account for in the projects listed above?

a. Less than 5%
b. 5 to 10%
c. 10 to 25%
d. 25 to 50%
e. More than 50% (Please specify________________)

18. If used, why were CASE tools selected to be used for requirements analysis?

a. Tools made task easier
b. Analysis more accurate
c. Directed to use tools
d. Done as a test case
e. Not used
f. Other (Please specify____________________)

Respond to the next four statements using the following scale:

Strongly disagree	Disagree	Neither	Agree	Strongly agree
A	B	C	D	E

_____ 19. Errors increased after using CASE tools.

_____ 20. Productivity increased when using CASE tools.

_____ 21. By using CASE tools, overall development costs increased.

_____ 22. Using CASE tools, time to complete the projects increased.

Computer Answer Sheet Number ______________________________

<u>COMMENTS</u> (Continue on the next page if necessary)

RETURN INSTRUCTIONS

Once you have filled in the computer answer sheet, insert the questionnaire and answer sheet in the return envelope and place the envelope in the mail.

Thank you for your time and assistance.

Appendix D - Control Group Raw Data

The following raw data was obtained from the computer answer sheets filled out when the surveys were completed. The data contains 91 cases.

DBCBEDBBFAAB

GA BDABBFFFCA

DAFAAABBFAF A   E

GCFEE

HBCBECABEFFDA   D

GCCCDEBBF FC AA

GAEA BBFF

GDEADDAB FFAADDCC BDCB

GDDBECABGFFB ABABECCCC

GDEBEDBBF AA   BDCB

HCACEEBBFDFDD   AAEDD

GACEDEABFFEAACCBDBBDBB

HE CEDBBG C

GBACEEBBFAFC   E

GBCBBEABEFFCA   ADCC

FBEBEEAB FFAA   CBDDD

GDDBEEAB FFABD   CCDCC

HCEEEEAB FFD   ACCCC

GCFBEDBB F C AA AE

HE AAABBFAAA   E

GD BEDBB F C AE

HCCBEEBBGFFC

DCAEDEBBFFFCA

DCFA ABBG FD

HEDEDEBBFFFC E

GBFAAABBGAADA

GCEBEEBBFFFDABA ADBB

HA BAABBGFAAAAA

FD ADCBBFFFBA BDBB

GCDB AB DFC C

DC BEEAA DFAC ADCB

DBEBDCBBGFFD

HC BEDAA ECCA E D

DAACE BBGFFD

DBABEDBBFAADAAD CCCC

GD C DBBFFFC

GCEC DBBGFFC

GAFA BB FF

GACCEEAABFFAC

HDFCCDBBFFF D

DBACDCAA CBBB DADAC

DCACDCAA CBAB DBCBB

DCAA AA CAABBCBCEBCBB

HCDECDBBFFFC

DABBAABBFAAA E

DCACECAAGFFAACC

HECEEDAA FFAD BDCB

GDDECEABGDAAB E

GDDECDAABBAACBCAAEBDBD

HEF

DBDECCABGFFABCD CDBDBB

GCACEDABBFFAA

DCABDCBBFAAC AA E

GDFEBBBBF C BA

DCCCEEABCD AAEDDDBCDBC

HECEEEAB FFCD

GBECEEBBF AAAB CCCC

GAFBEDBBF

GEDACEBBFAABAEA ECCCC

DCABEEAAAFFBD ABDBB

DDCAAABBFAAAA E

DCCEEEAB FFB

GBFCED GFFB FCCCC

DDCDDD F AAAA

E

DBFAAA G

DA E D G

GEABBCBBFAACA

DDAEEE G B

DAEEECABGFFDDCBCCCCCDD

DC EEEABGFFBBDC D DDDC

DA EEEA EBCB ACBB

GCFAAEBBFAABAAAAAE

DCCBEE GFFB

GDEAEDBBFFF

HE EEEAA CC A ABDB

GACBE AA FF

GDBEEDBBFAAB E

GBF F

GD B B F AA ECCCC

GEEA B F AA

HEFA B FAADABD E

DAEBEE G B E

HDF G C

EDF

DCAACCABCFFCA

GCEBEEBBEDA A ABDBB

GD BCCABGFFCA D

DBFBDEABFFEBA

EEAEDDABFFDDABDADECCCC

DCFBEABBFAFBAAA

Appendix E - Frequency Distribution Charts of Control Group Responses

Introduction

The following frequency distribution charts represent the answers provided by the control group. Of the 22 questions, questions 3, 9, and 18 were not graphed using a frequency distribution because respondents could provide multiple answers to these questions. Tables of the answers to these three questions can be found in Tables 4-1 through 4-3 in Chapter IV.

Frequency Distribution Charts

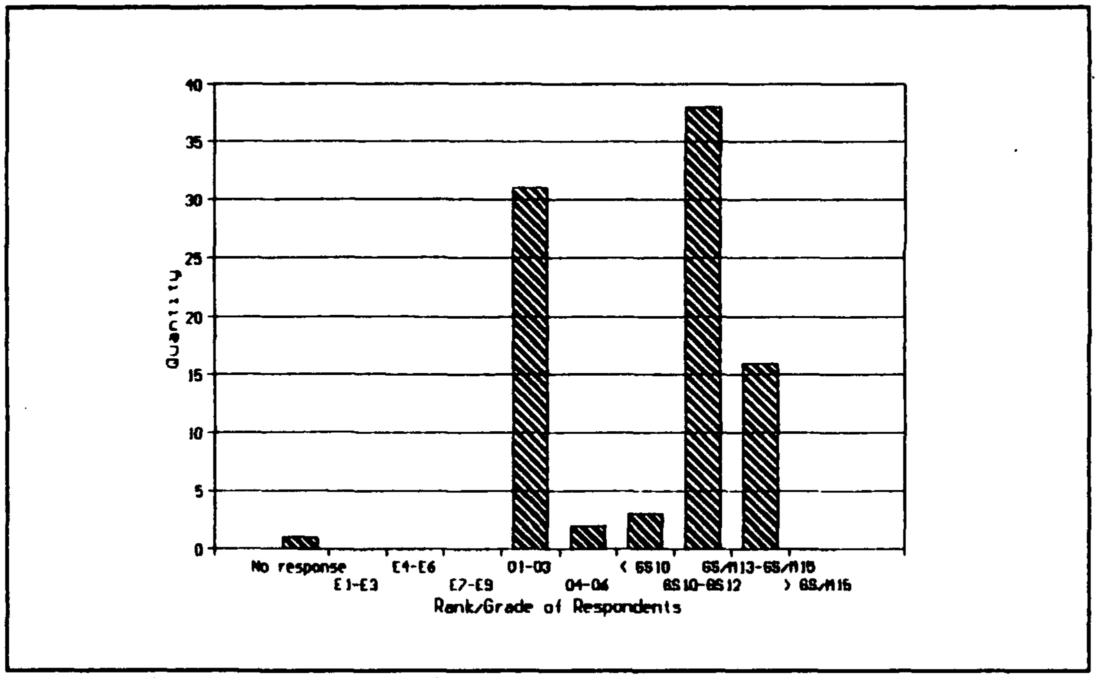

Figure E-1. Rank and Grade of Control Group

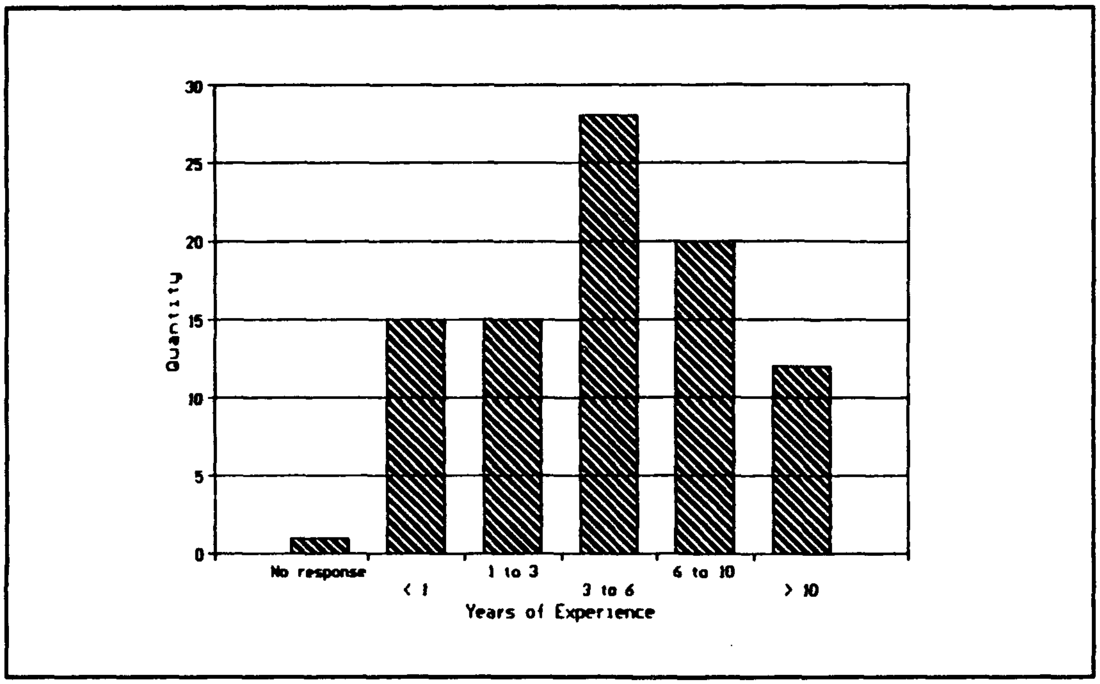

Figure E-2. Experience Levels of Control Group

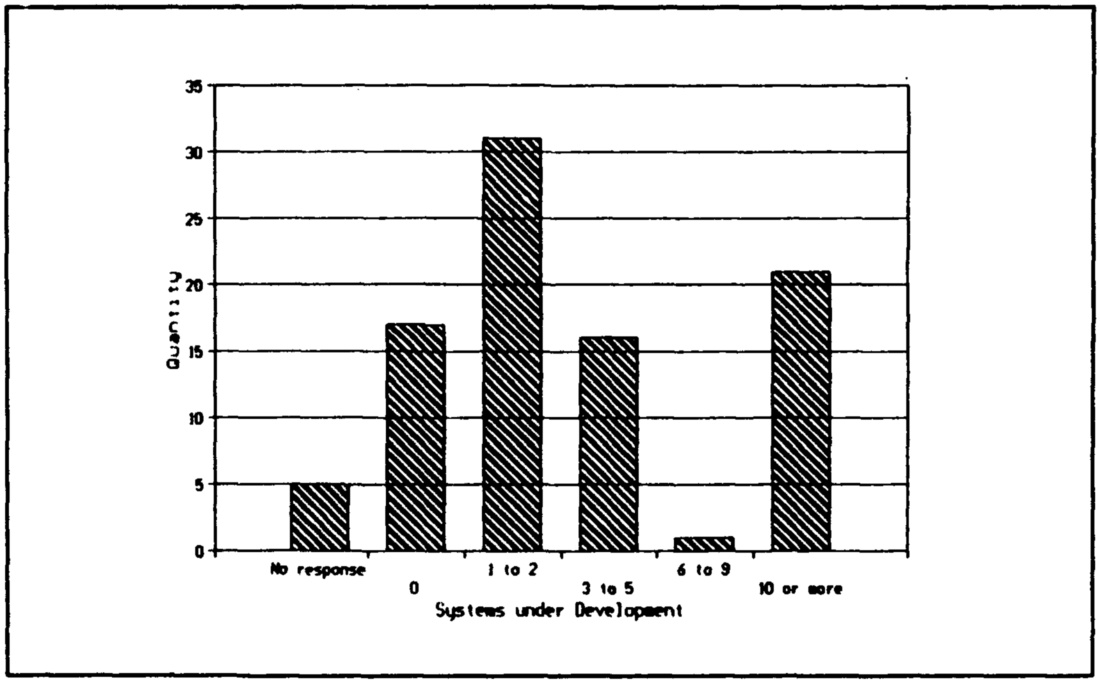

Figure E-3. Number of Systems in Development by Control Group Organizations

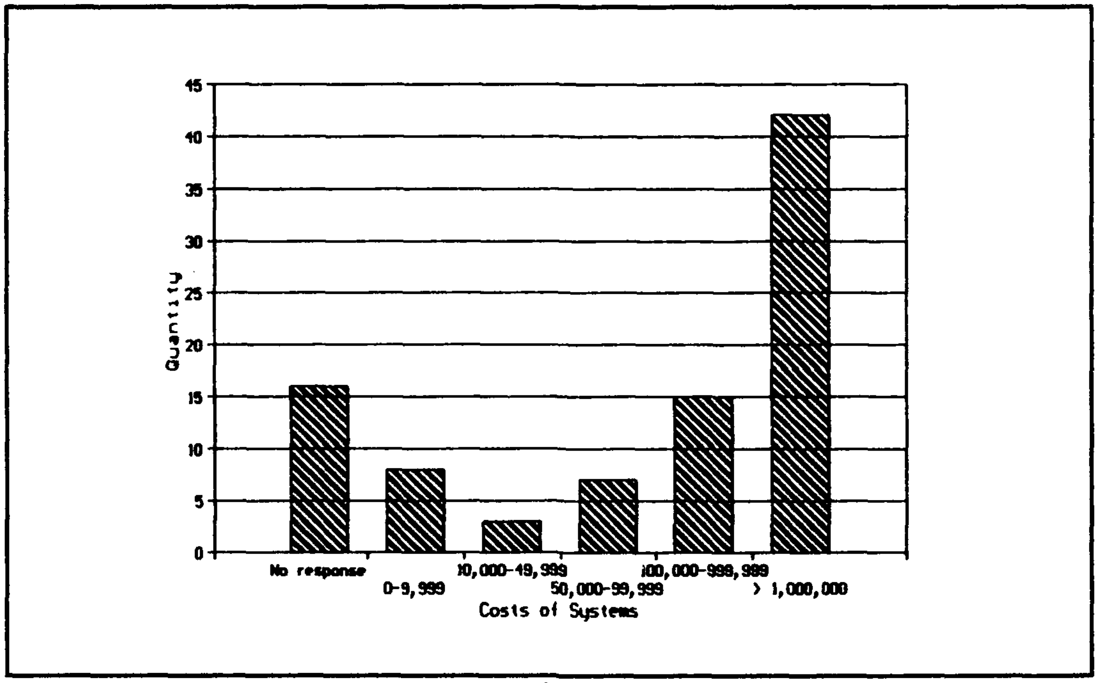

Figure E-4. Cost of Development Systems in Control Group Organizations

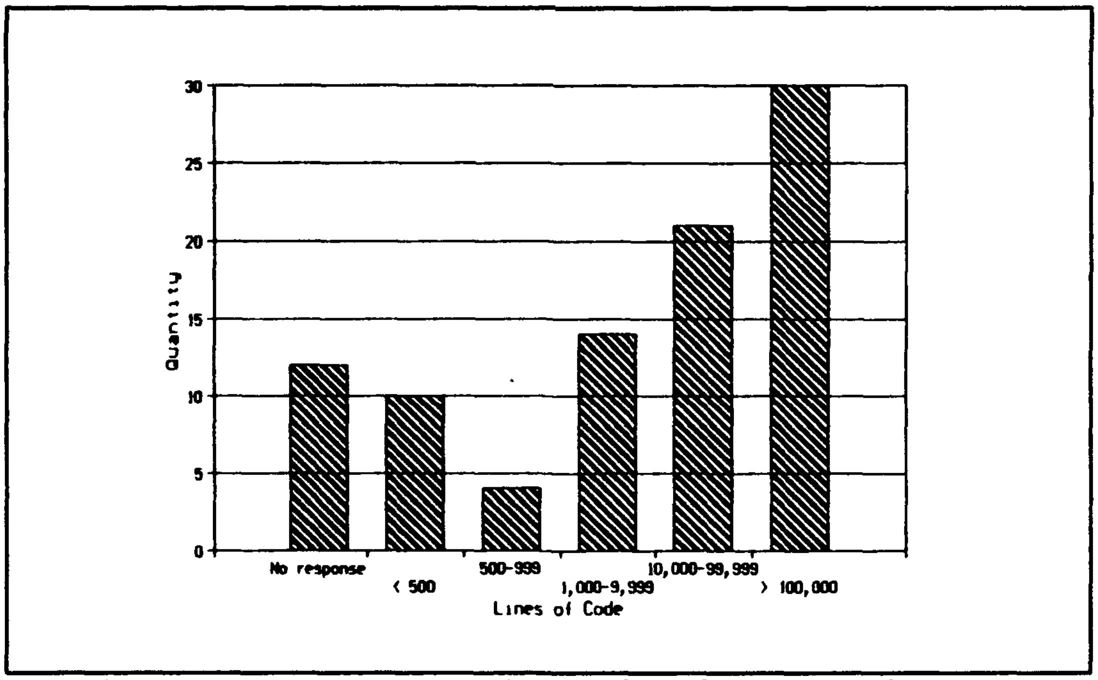

Figure E-5. Average Lines of Code in Development Systems in Control Group Organizations

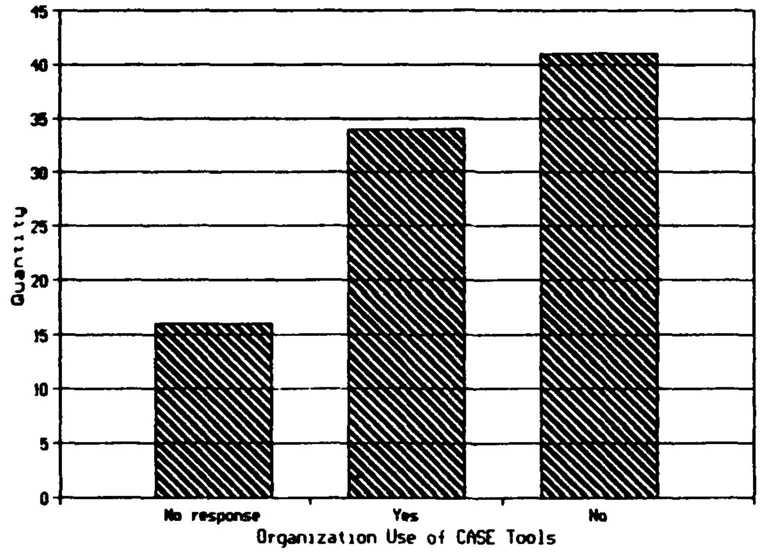

Figure E-6. Determining Number of Control Group Organizations that Use CASE Tools

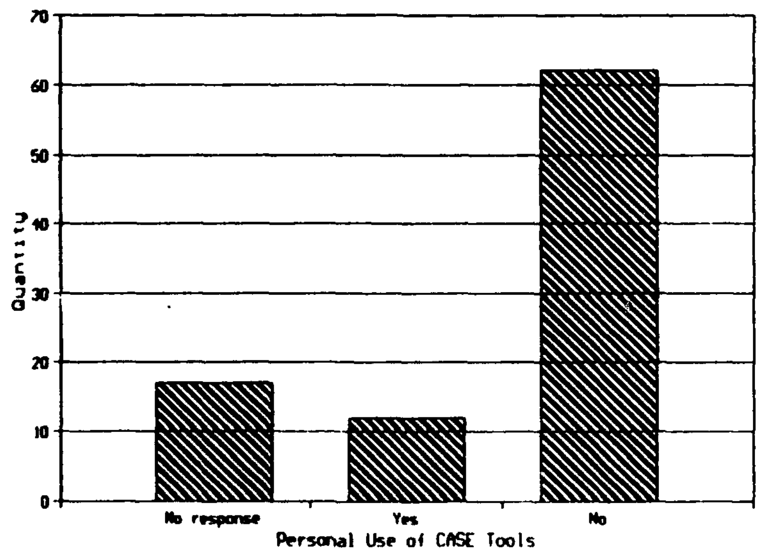

Figure E-7. Determining Number of Control Group Respondents that Use CASE Tools

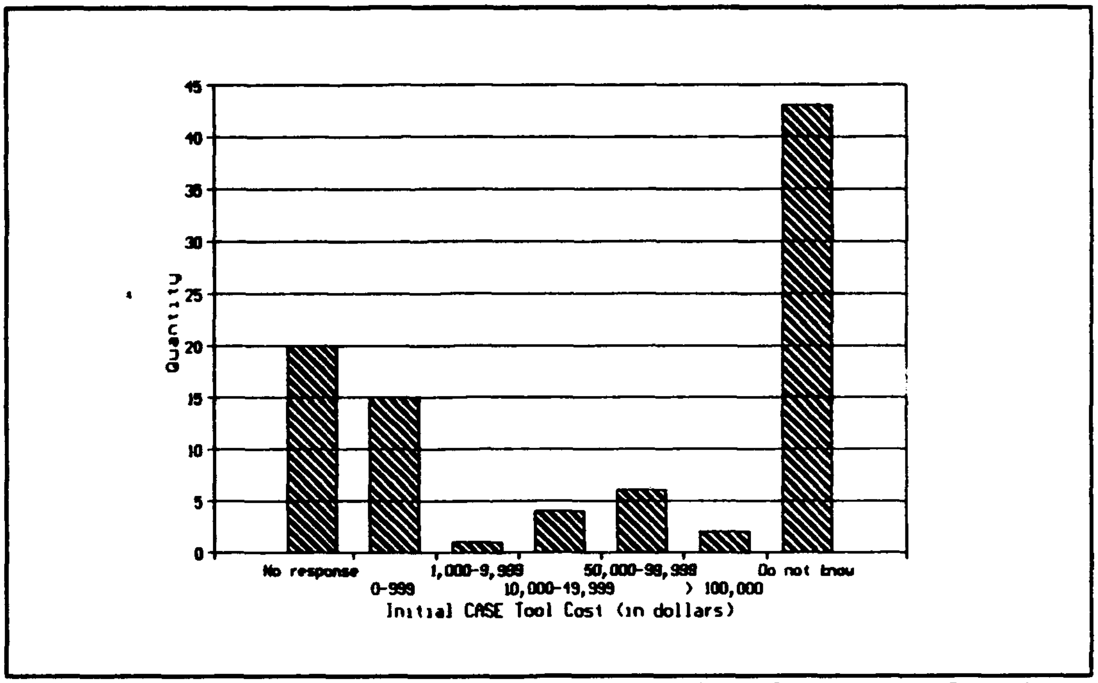

Figure E-8. Determining Average Initial Costs of Using CASE Tools in Control Group Organizations

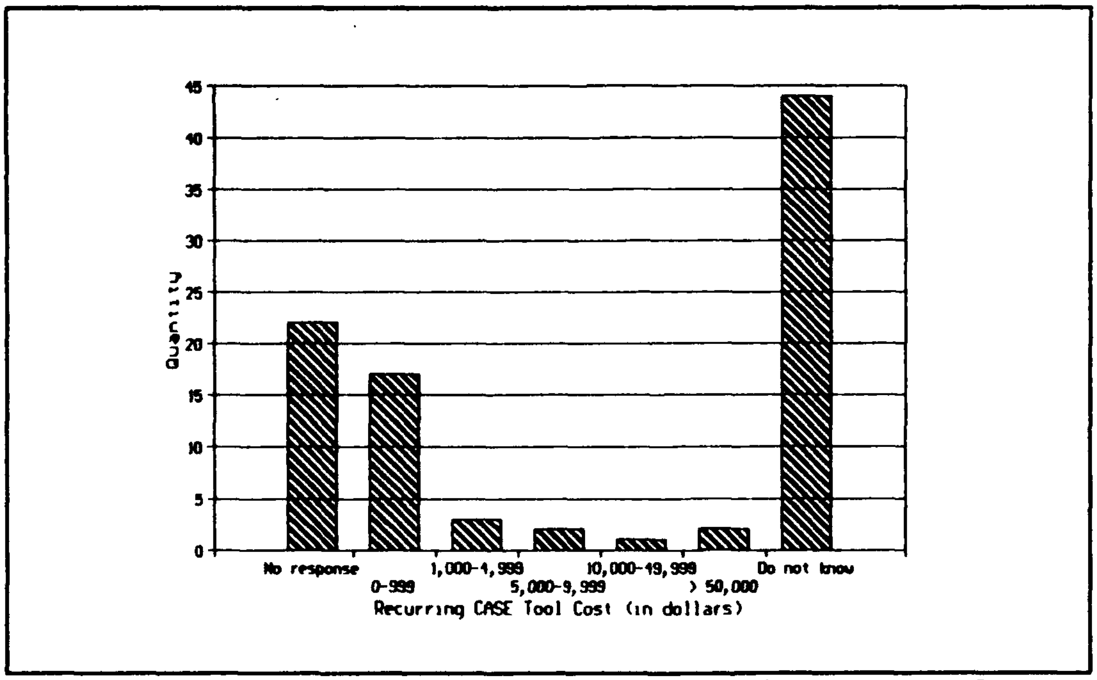

Figure E-9. Determining Average Recurring Costs of CASE Tool Use in Control Group Organizations

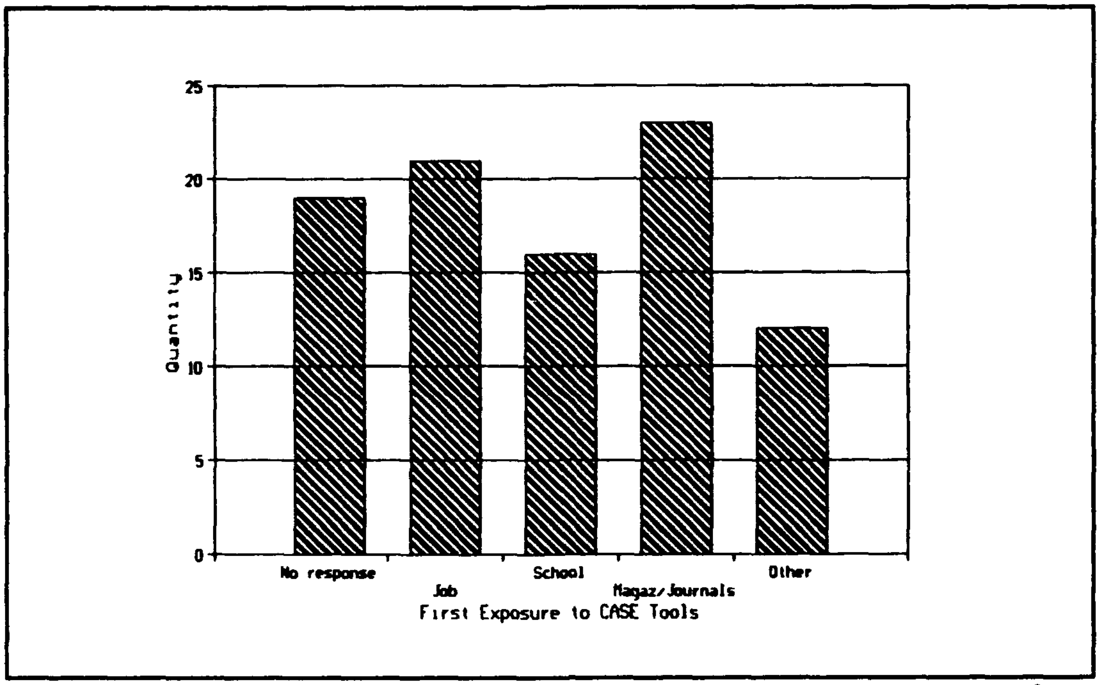

Figure E-10. Determining First Exposure to CASE Tools in Control Group

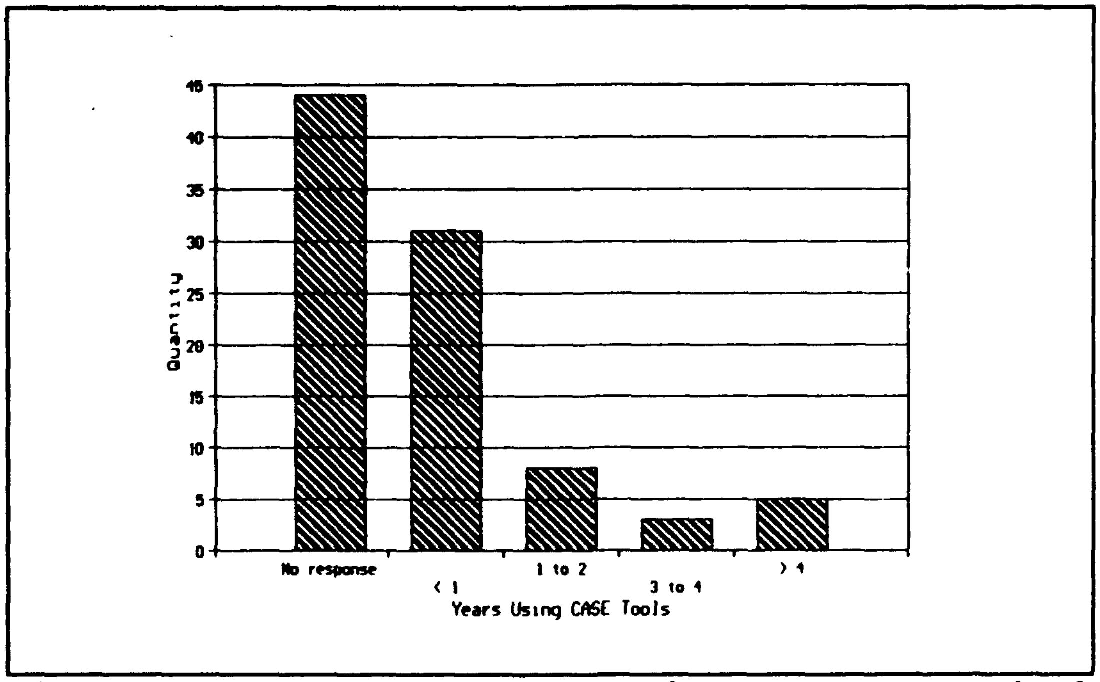

Figure E-11. Determining CASE Tools Experience Level of Control Group Respondents

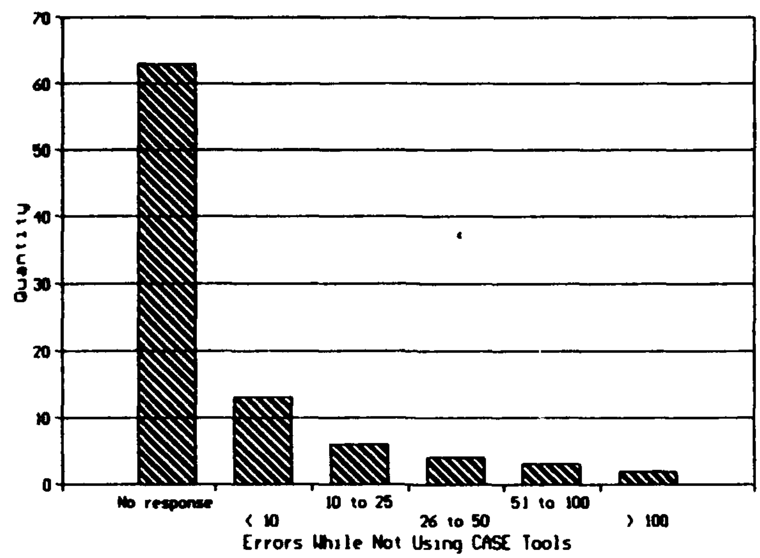

Figure E-12. Requirements Analysis Errors/KLOC of Control Group Organizations Not Using CASE Tools

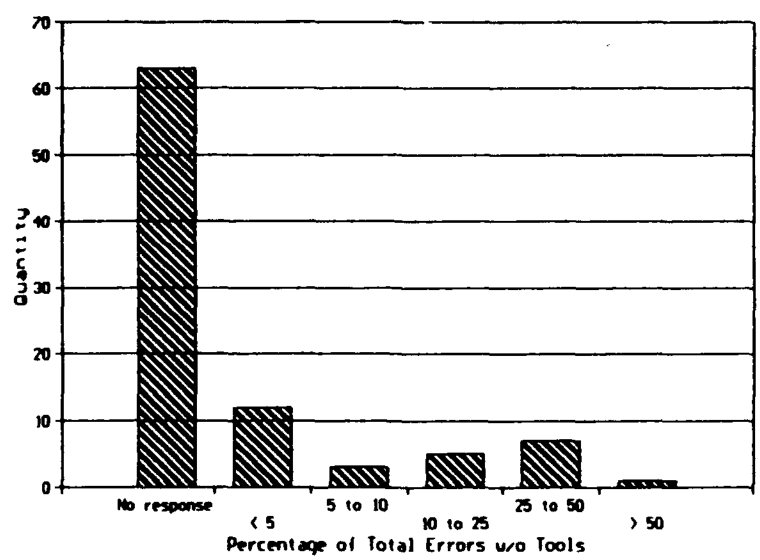

Figure E-13. Percentage of Total Errors Credited to Requirements Analysis in Control Group Organizations Not Using CASE Tools

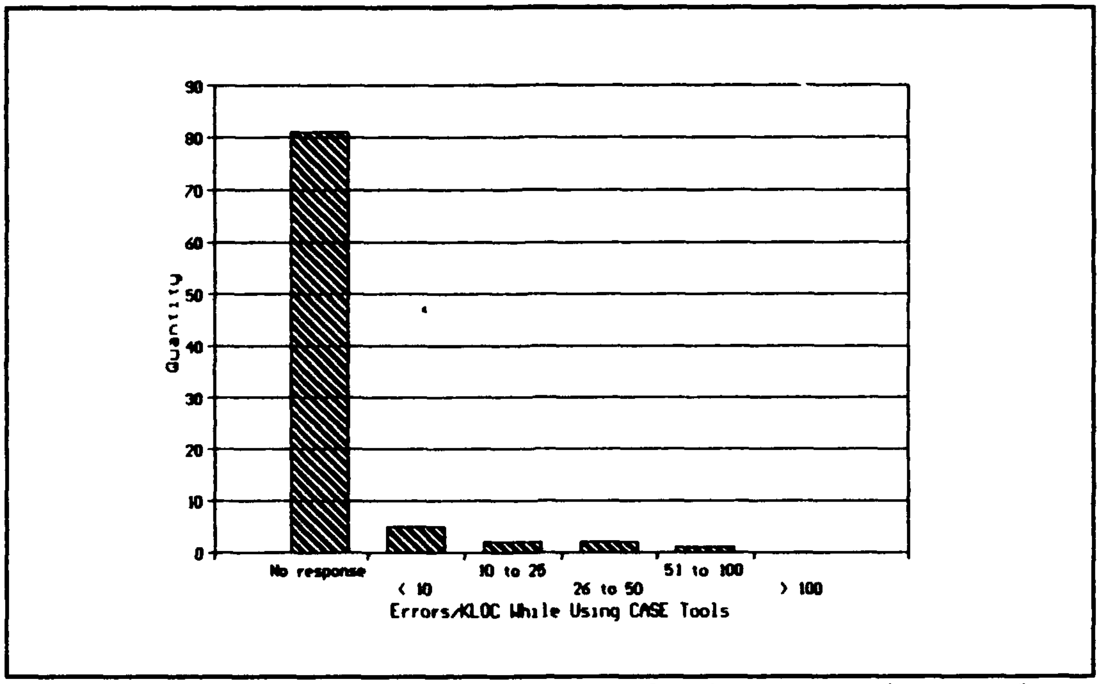

Figure E-14. Requirements Analysis Errors/KLOC of Control Group Organizations Using CASE Tools

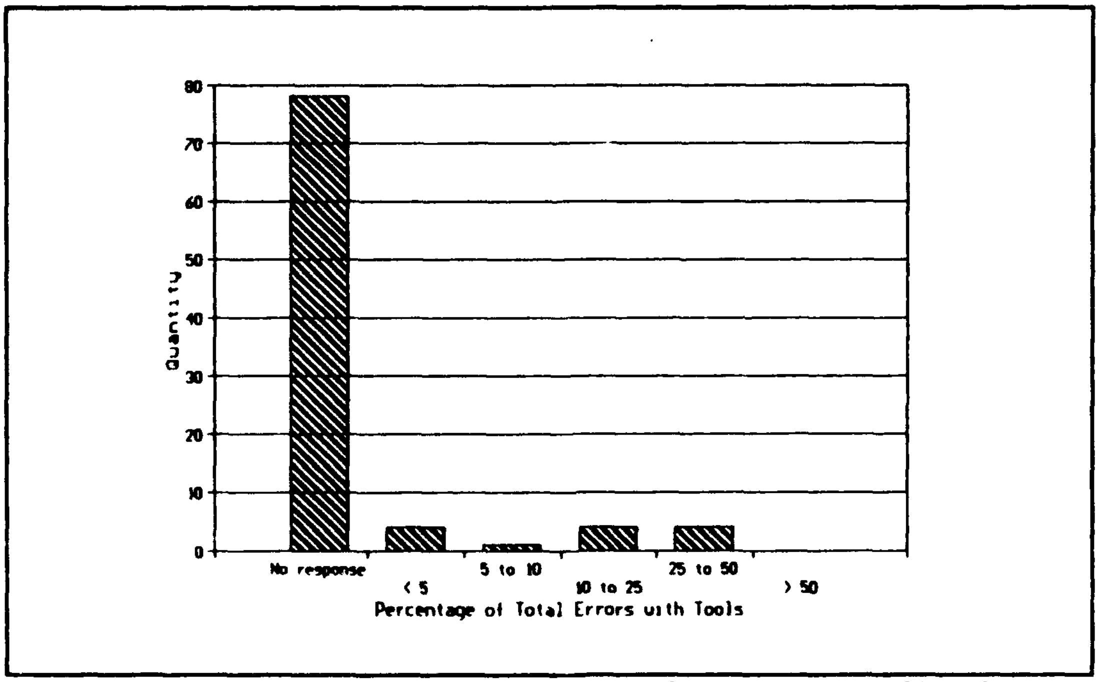

Figure E-15. Percentage of Total Errors Credited to Requirements Analysis in Control Group Organizations Using CASE Tools

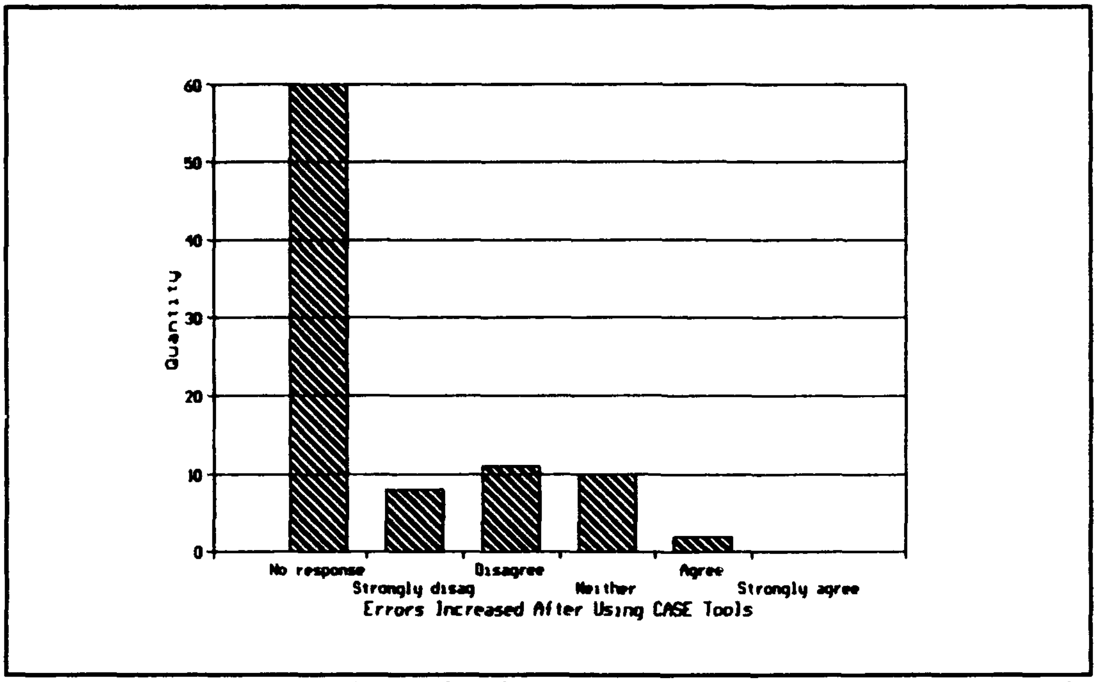

Figure E-16. Rating Whether Using CASE Tools Increased Error Rates in Control Group

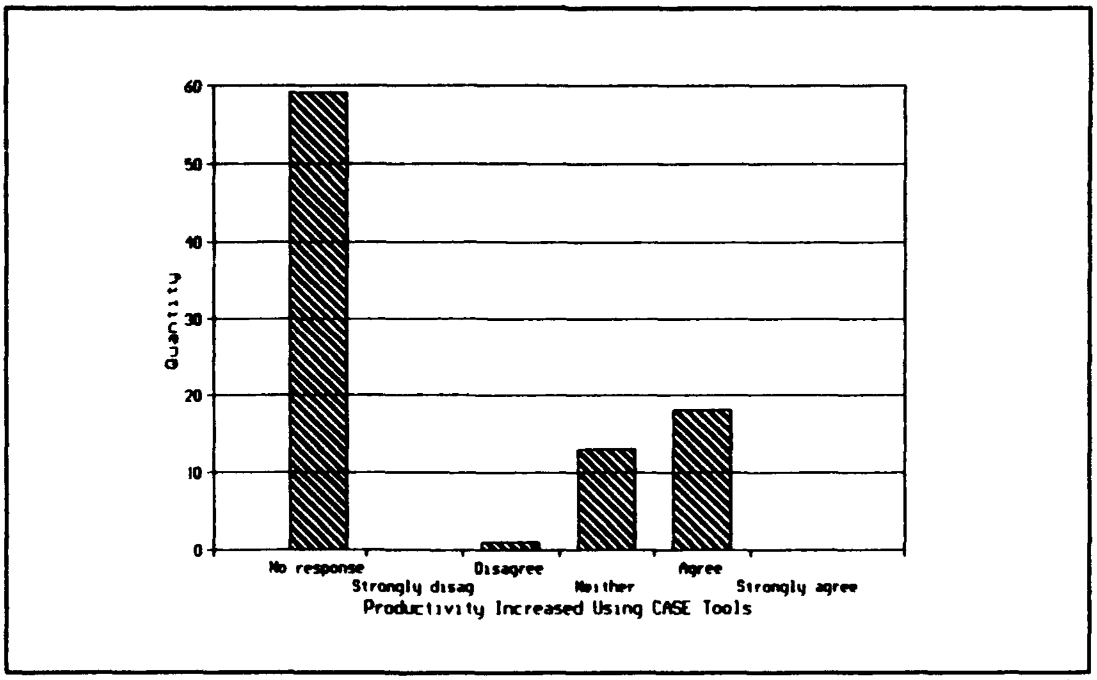

Figure E-17. Rating Whether Using CASE Tools Increased Productivity in Control Group

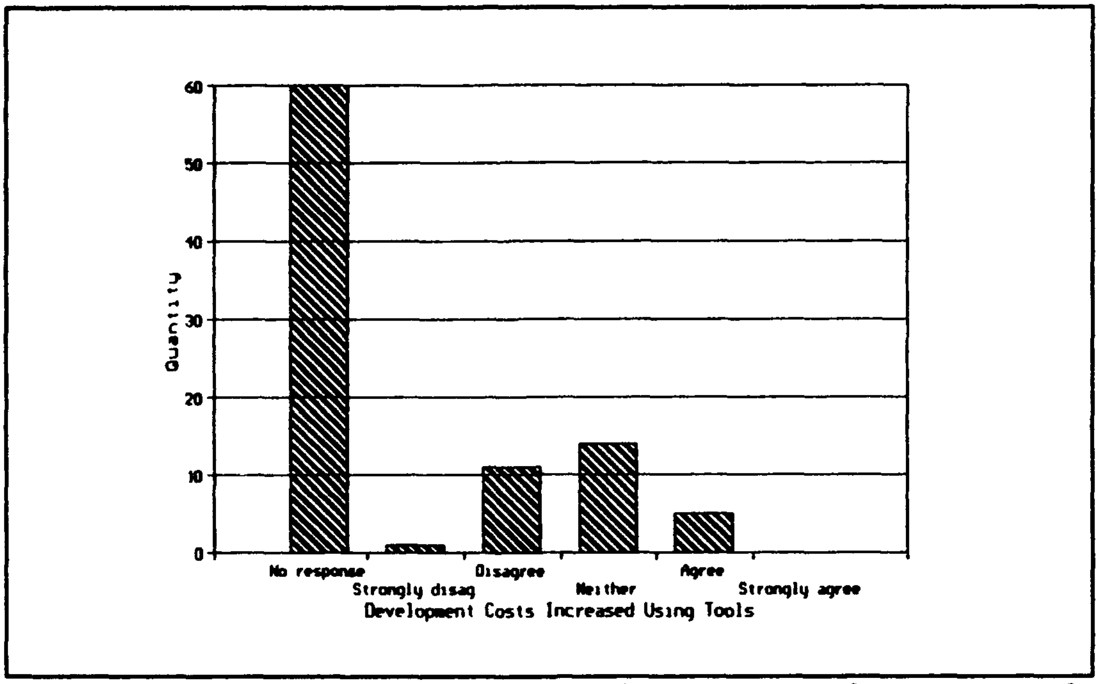

Figure E-18. Rating Whether Using CASE Tools Increased Development Costs in Control Group

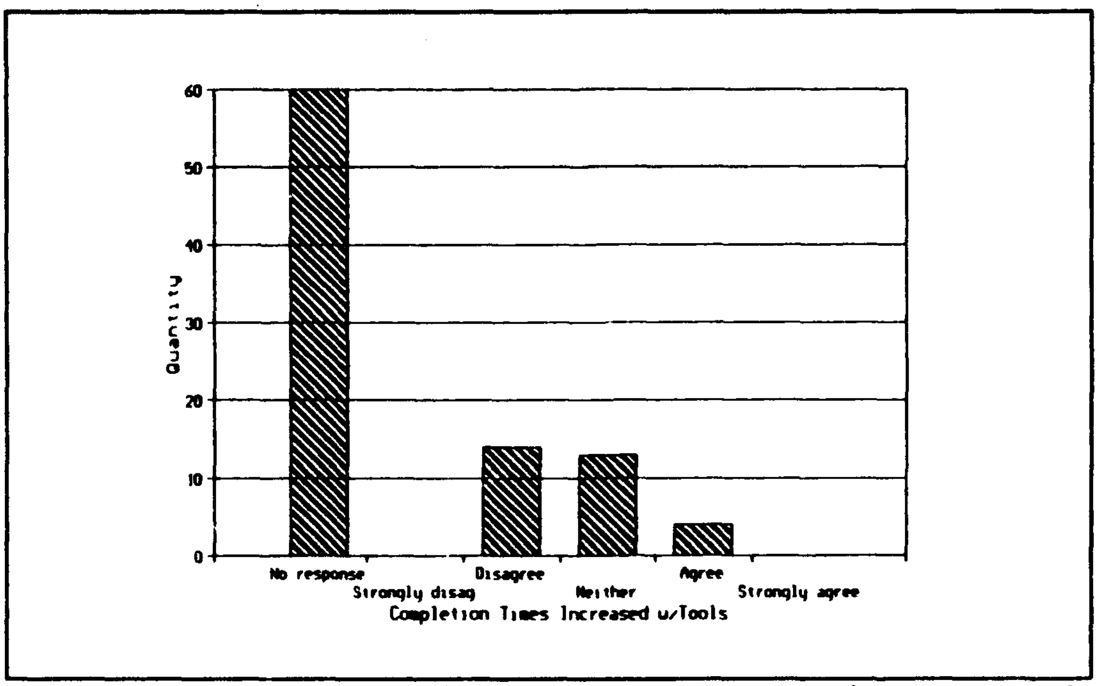

Figure E-19. Rating Whether Using CASE Tools Increased Time to Complete Projects in Control Group

Appendix F - Sample Group Raw Data

The following raw data was obtained from the computer answer sheets filled out when the surveys were completed. The data contains 67 cases.

```
DBDBCDAB FFA
DADAAAABCBBBAB AD BDCB
DE AEEBBFAAAA    ECCCC
DBCAEDAAECCDA    DBCCC
DB DEEAB FFAA    CBDCB
DDBADCBBFFFBAC   E
DAABACABFFFBABCACECDDD
DEAAACBBFAABAAAAAECCCC
DBFAAAAA AABB    ACECA
DBFBABBBFFFBACB  E
DCABDDBBF  BADD  E
DEDBAEAA BABBBDCDCBCCD
DCEBCDBBF FBABB  F
DDABEEAA CFAAEEDE AEBB
ECBCEEBBBFFFBA   E
EBCBEEAA EEADCDACBAEBB
EBABDDAA CACB    ECCDB
BBFBCCAA FFABBBAAABCCC
DDAAEDABGFFBAAAAAECCBB
GDACBCBBF  D AB
CEADACBBFFFC AAAAECCCC
```

DDDCDDABBFFBB C CEBDBB

DEBACCABFFFCAAAABECCCC

DEBCCCBBFFFCAAAAAE

DCCAACBBFFF

DCABDEAA FFBB   ABCCC

HEEAEEBB   A   BDBA

DCBBBDBBF B BB E

GA BBBAAEFAACBCAAD

HECBEEAA FFBDDDBC BDBB

DCABCDBBFFFBACCCCCBDDD

GCBBEDBBFAAABDDDDAADBC

BDDCDEBBFBACAAAAAECCCC

GCEBEDBBFFFAABB   AEBB

CC CEEAB FFAC   C C

IDDAB CAA BABB   BACCC

ICABABAA BAABAAAAECDCB

GAFBCCBBFAABA   ECCCC

HECBDDAAEDFBA D A

GEFAAABBGAFDAABAAECCCC

DDEBDCBBFAA AA AE

HECCEDAA EFCD   CECC

BADBCDBB FFA AAAA A

BADBDDBBGFDAABBBBECCCC

GD BCDBBFABCABEBEECDDC

GBDBEEBBF D DD E

HEDBDDAA CCDADC DBDCC

DDDCCCAA FAABBBAA ADDB

DCABCDABFFFABDC CECCCC

DADBBDAB DDAABAAAABCDD

GCCBBBABFFCBA

GEBCDDAA FFCAAAAAEBDBB

DDBCACBBFFFBAAAAAEECBB

DDBCDDABFFFCA

IEFBBDCBBFFFCABBCECCCC

DDDAAABBF   E

CADBBDBBFADC   ECCCC

DBDCEEAB AEAC   AADCB

DEBBDDAA FFADCDAC BEAB

HEDBDDAA CCCBCBBBEBDBB

DCABEEBBFFFB   CCCC

DBCBFEBBF   AA   E

DAADEDABAFEAACCBBDBCBB

DCABCDABFFFABDC CECCCC

BADBDDBBGFDAABBBBECCCC

DDAAEDABGFFBAAAAAECCBB

DEAAACBBFAABAAAAAECCCC

Appendix G - Frequency Distribution Charts of Sample Group Responses

Introduction

The following frequency distribution charts represent the answers provided by the sample group. Of the 22 questions, questions 3, 9, and 18 were not graphed using a frequency distribution because respondents could provide multiple answers to these questions. Tables of the answers to these three questions can be found in Tables 4-4 through 4-6 in Chapter IV.

Frequency Distribution Charts

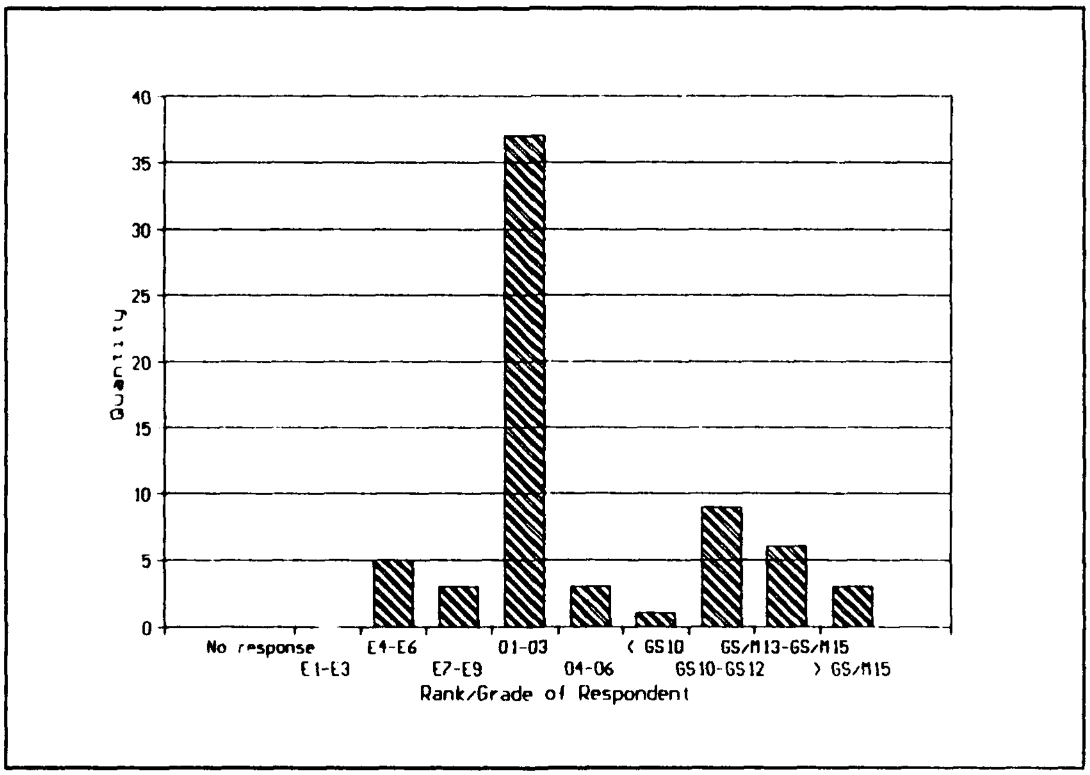

Figure G-1. Rank and Grade of Sample Group

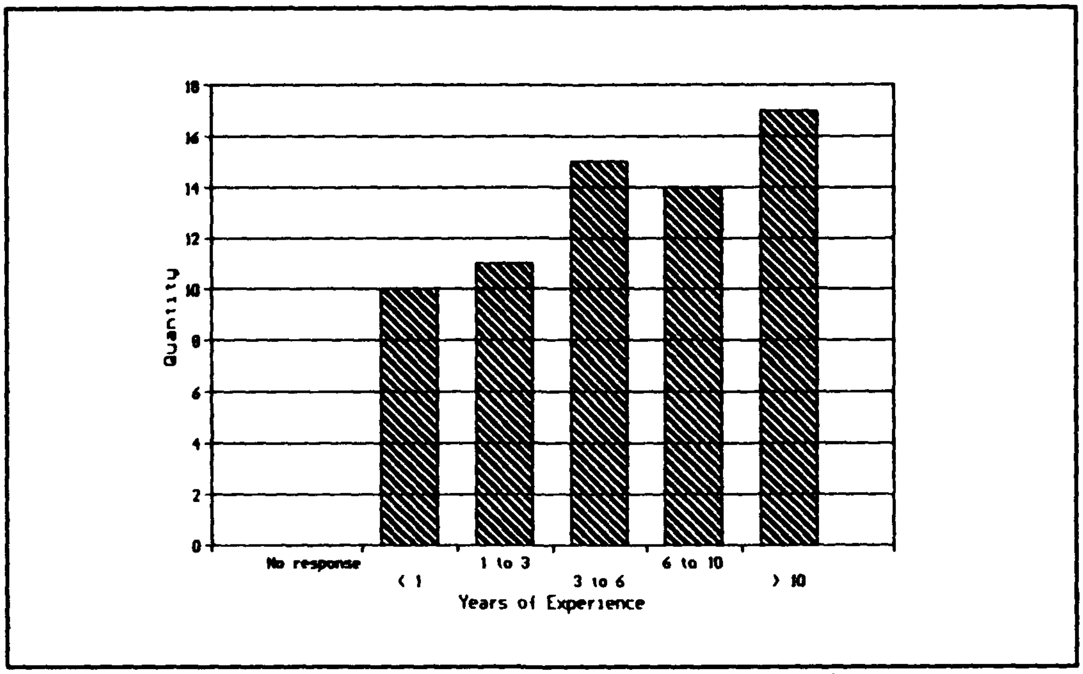

Figure G-2. Experience Levels of Sample Group

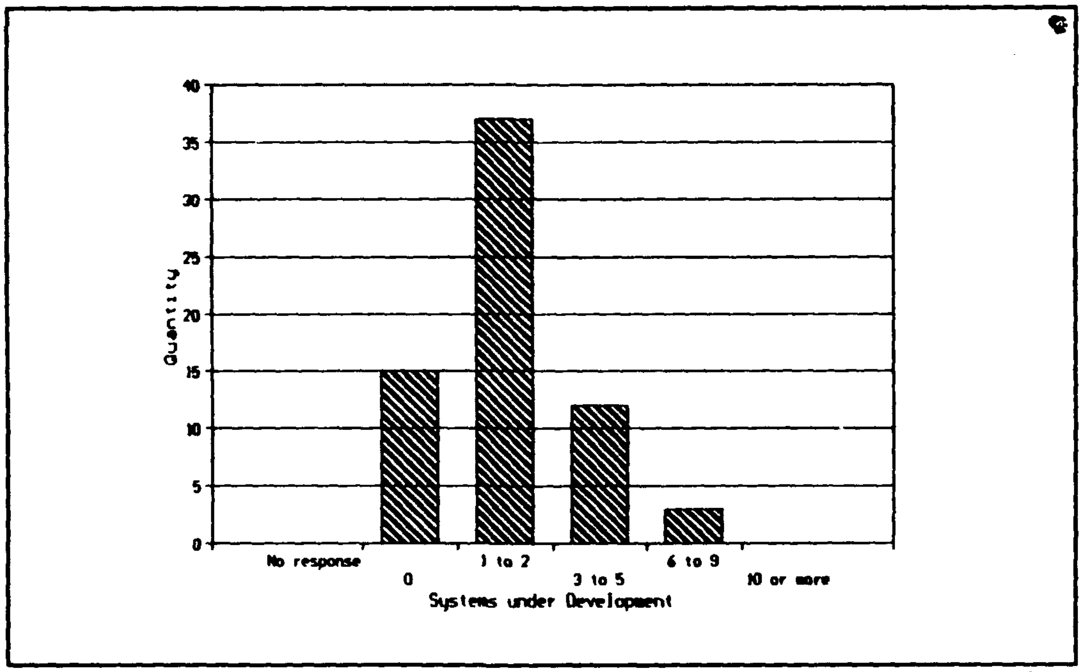

Figure G-3. Number of Systems in Development by Sample Group Organizations

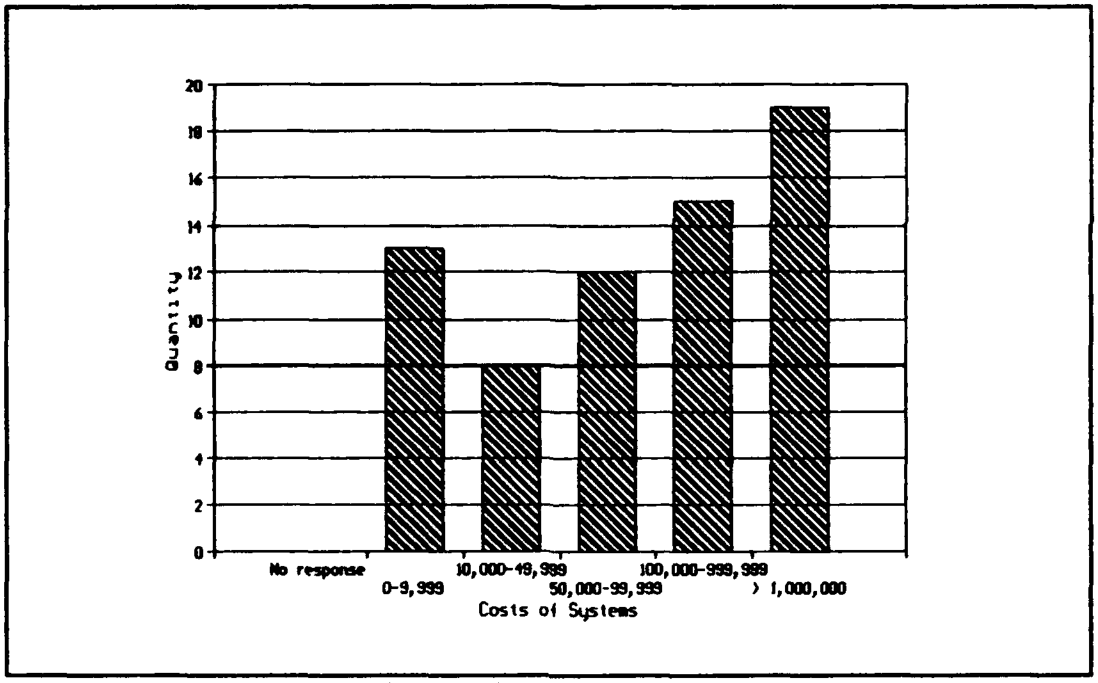

Figure G-4. Cost of Development Systems in Sample Group Organizations

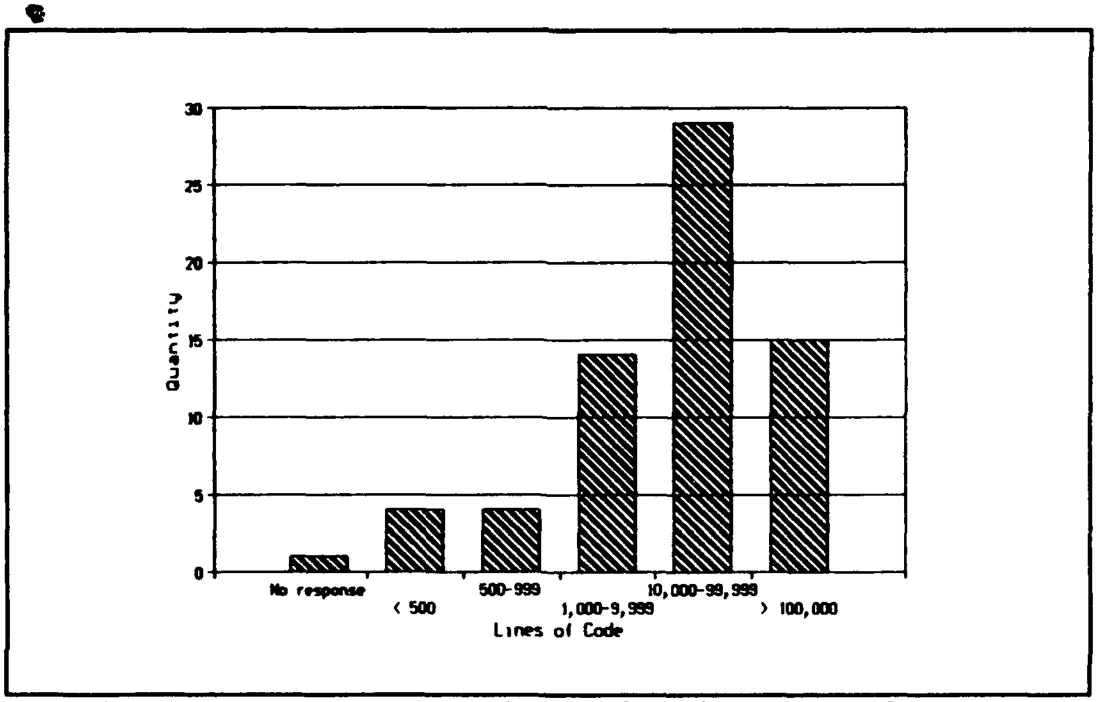

Figure G-5. Average Lines of Code in Development Systems in Sample Group Organizations

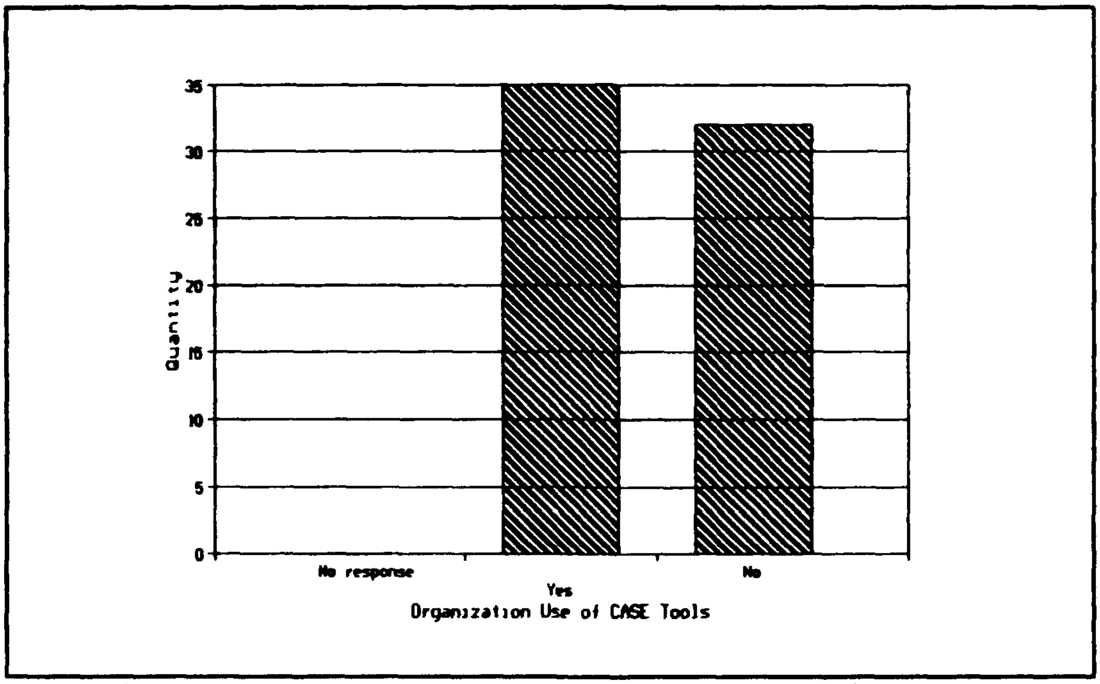

Figure G-6. Determining Number of Sample Group Organizations that Use CASE Tools

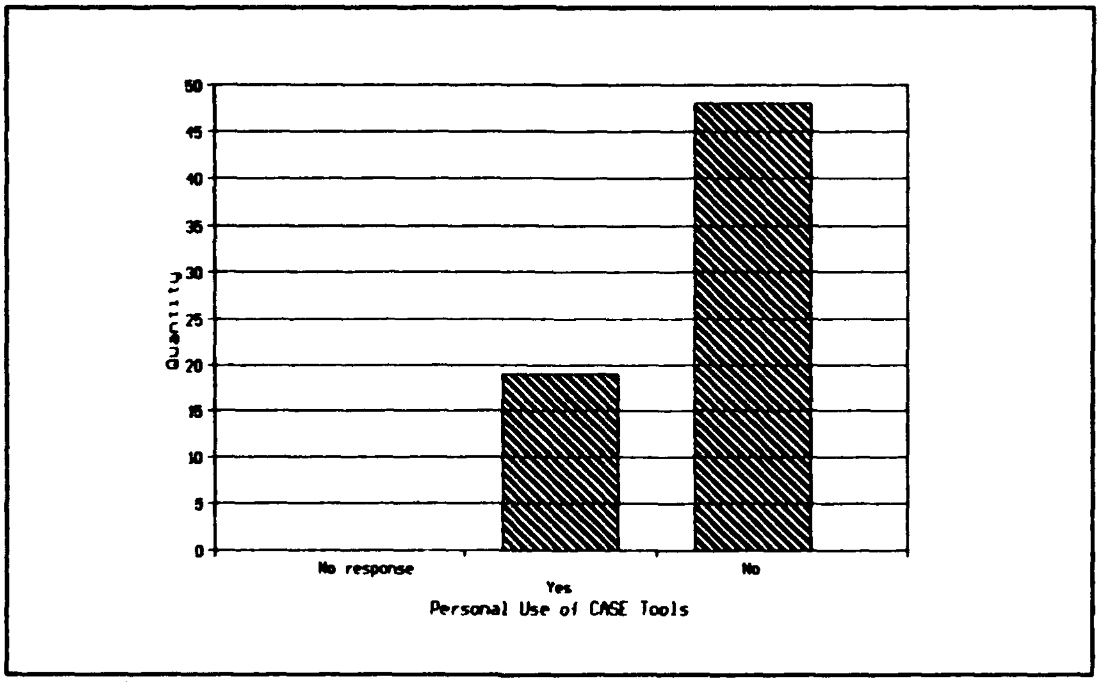

Figure G-7. Determining Number of Sample Group Respondents that Use CASE Tools

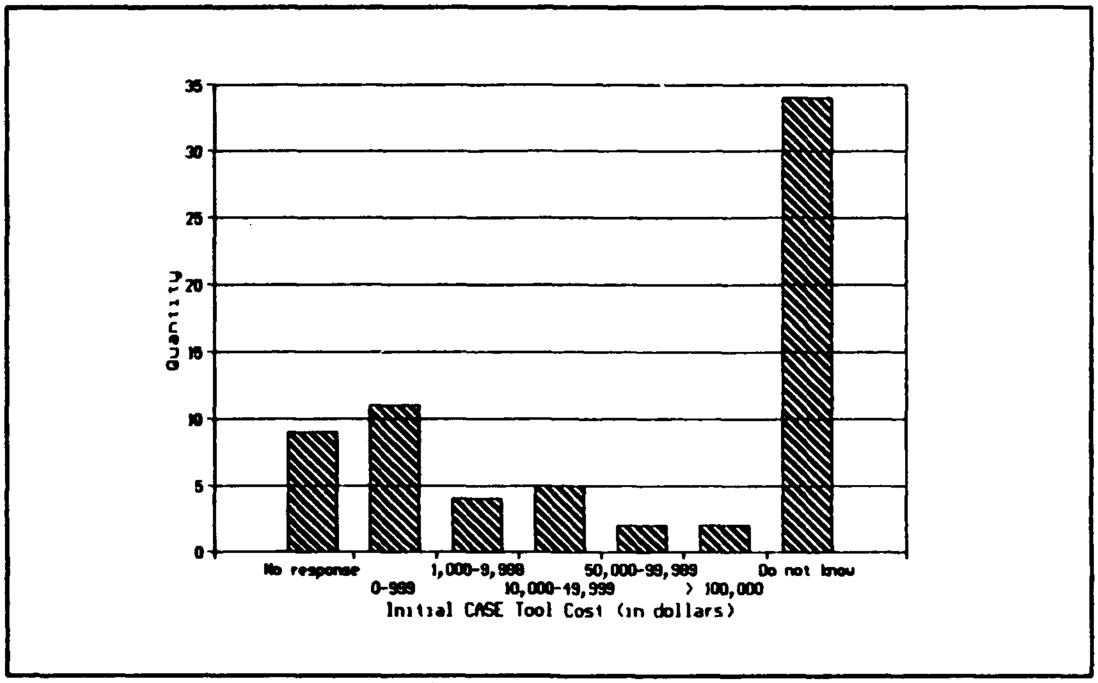

Figure G-8. Determining Average Initial Costs of Using CASE Tools in Sample Group Organizations

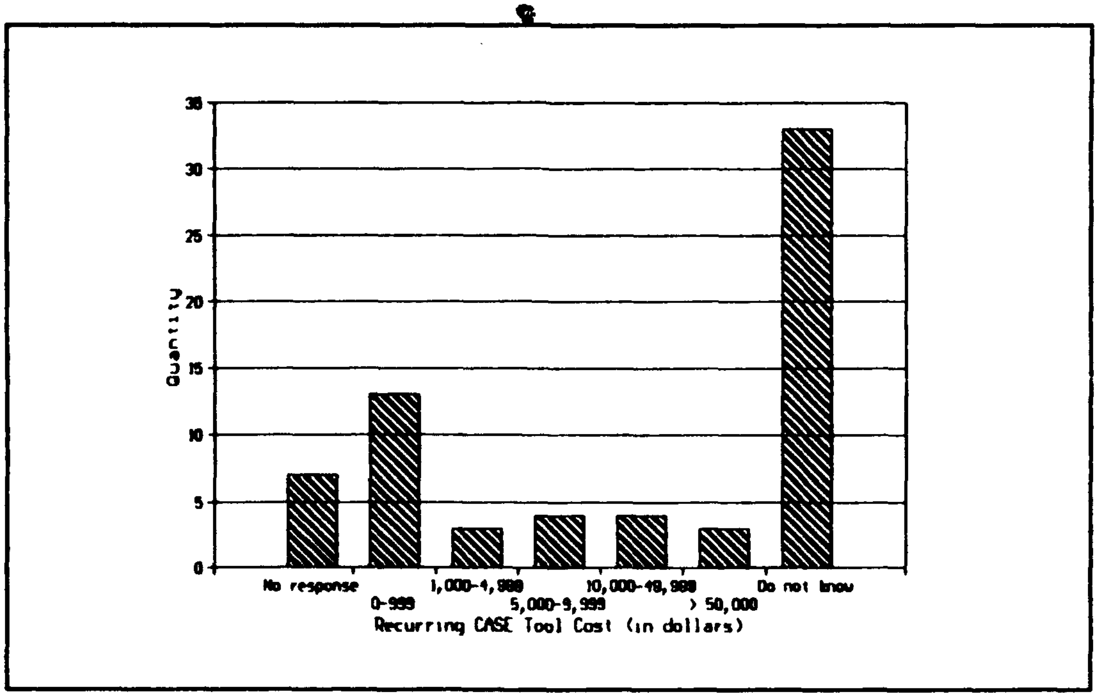

Figure G-9. Determining Average Recurring Costs of CASE Tool Use in Sample Group Organizations

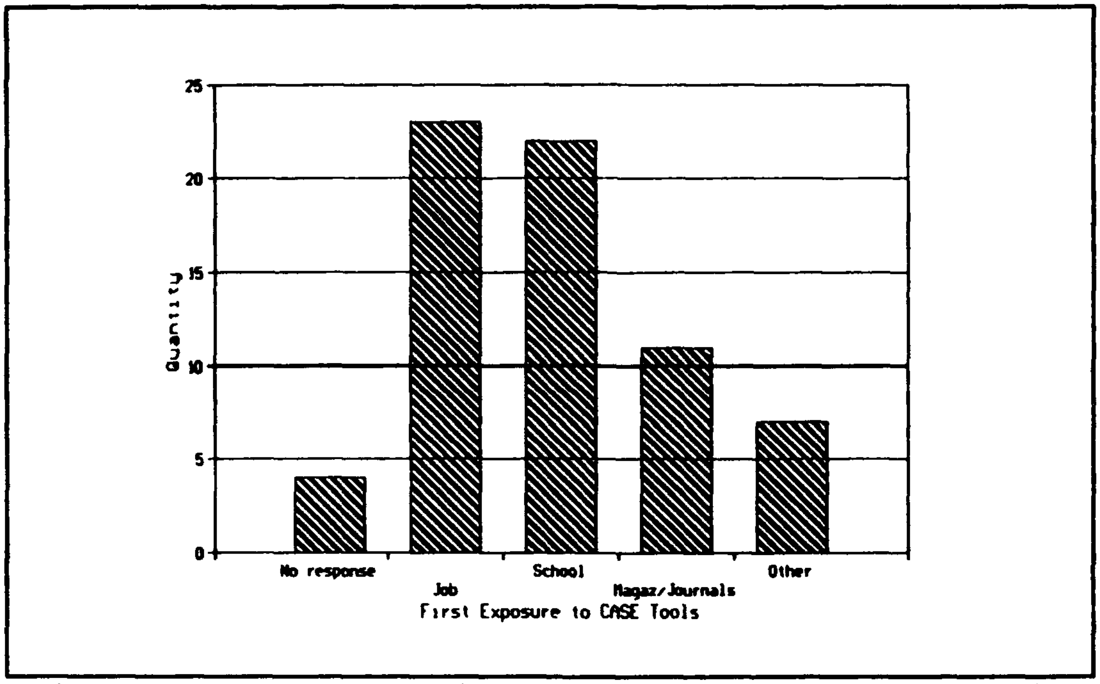

Figure G-10. Determining First Exposure to CASE Tools in Sample Group

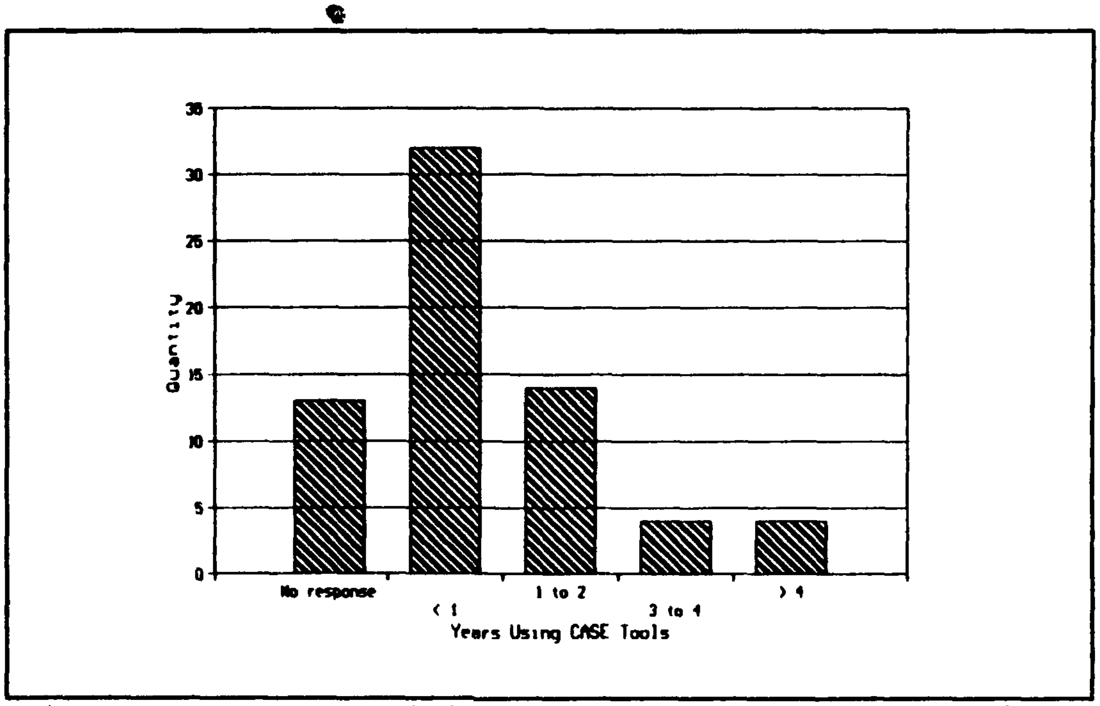

Figure G-11. Determining CASE Tool Experience Level of Sample Group Respondents

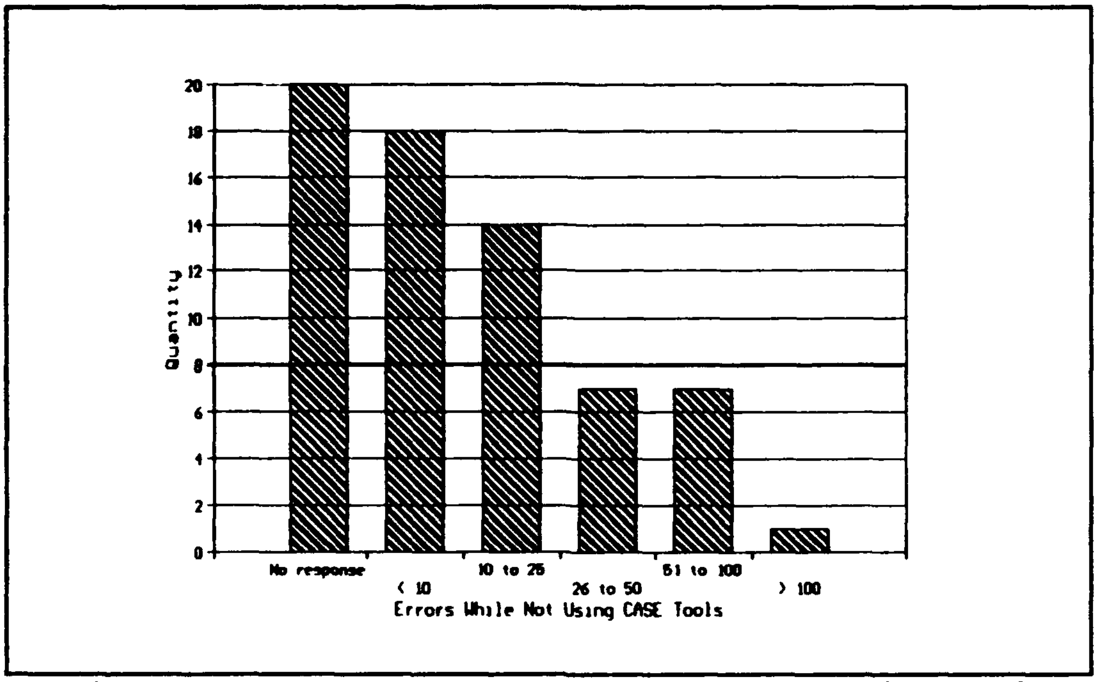

Figure G-12. Requirements Analysis Errors/KLOC of Sample Group Organizations Not Using CASE Tools

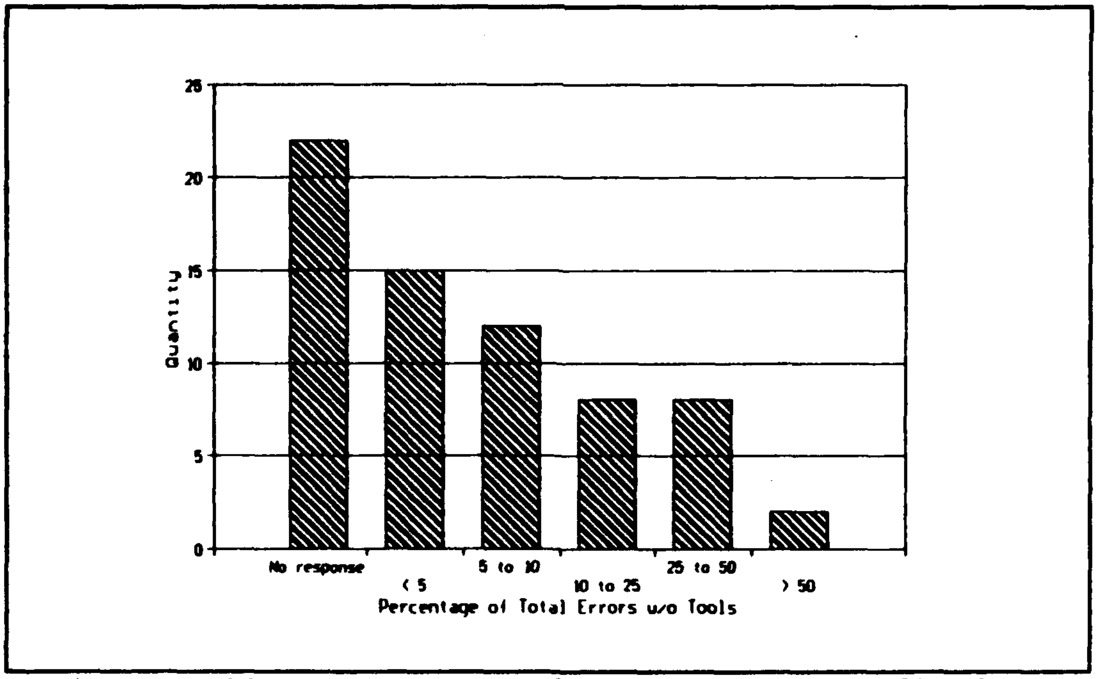

Figure G-13. Percentage of Total Errors Credited to Requirements Analysis in Sample Group Organizations Not Using CASE Tools

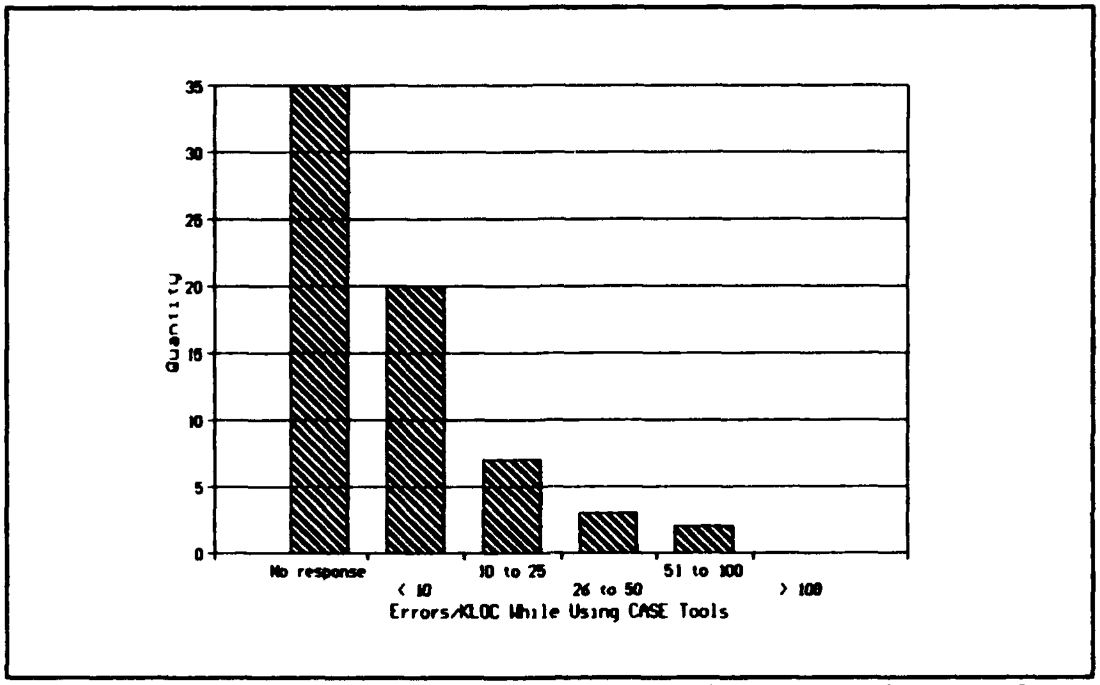

Figure G-14. Requirements Analysis Errors/KLOC of Sample Group Organizations Using CASE Tools

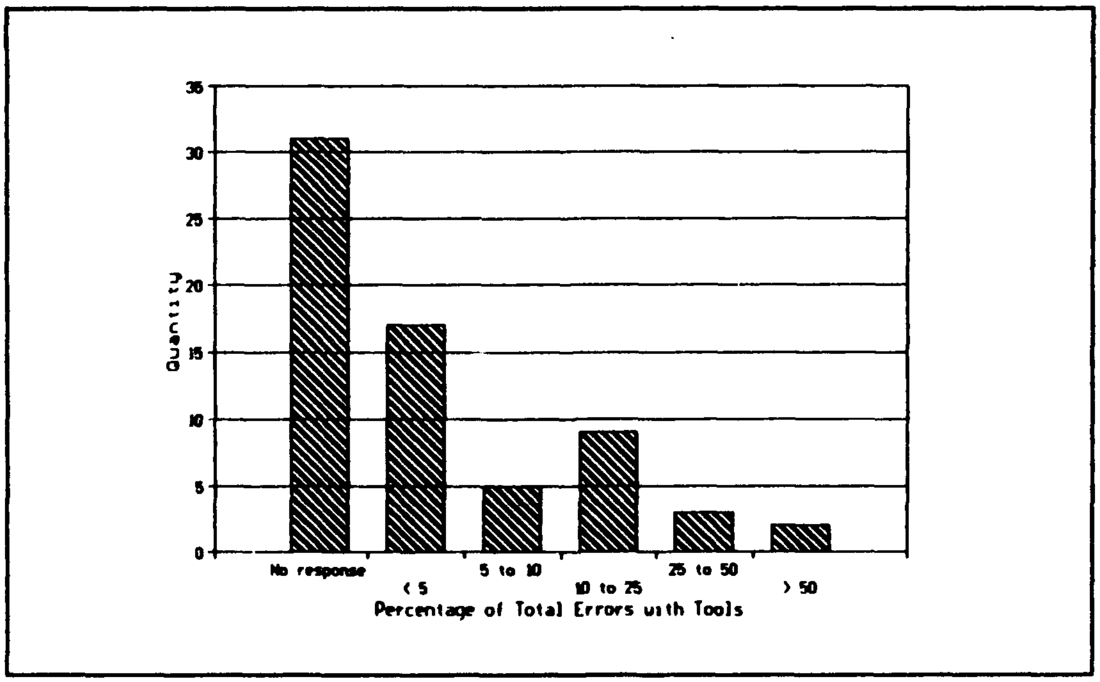

Figure G-15. Percentage of Total Errors Credited to Requirements Analysis in Sample Group Organizations Using CASE Tools

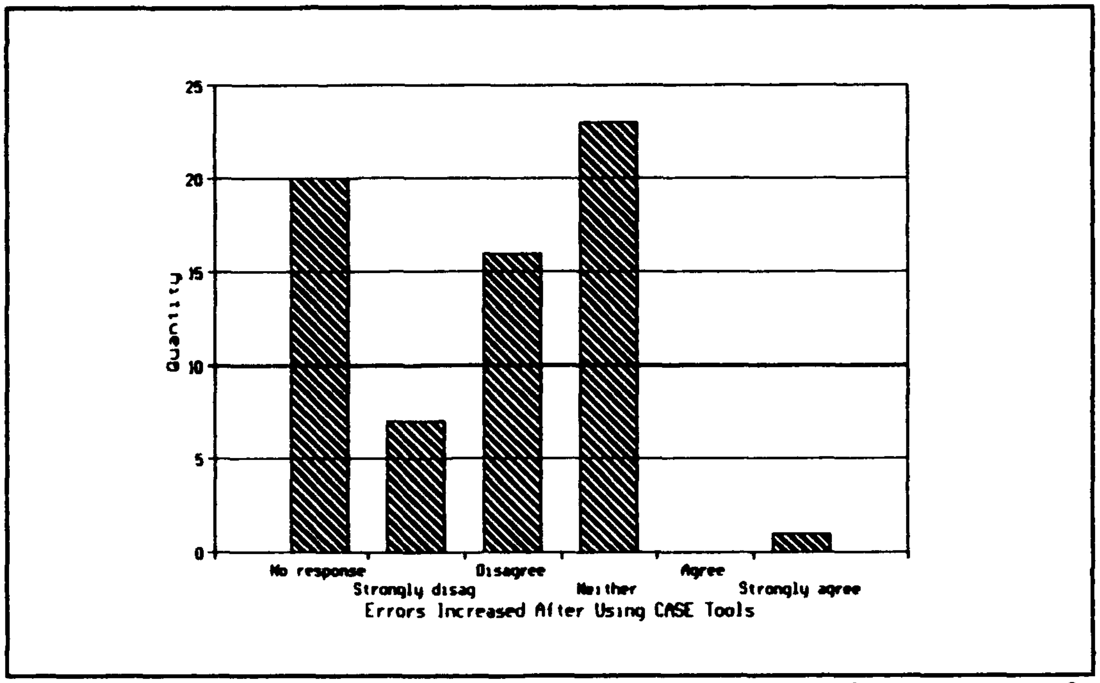

Figure G-16. Rating Whether Using CASE Tools Increased Errors Rates in Sample Group

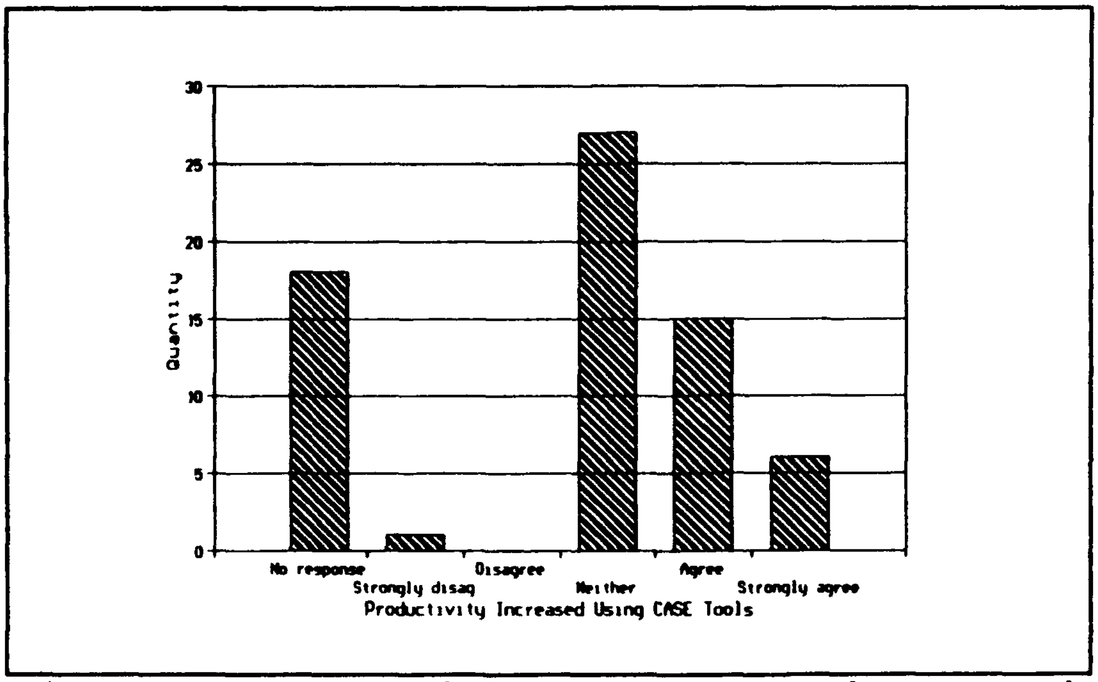

Figure G-17. Rating Whether Using CASE Tools Increased Productivity in Sample Group

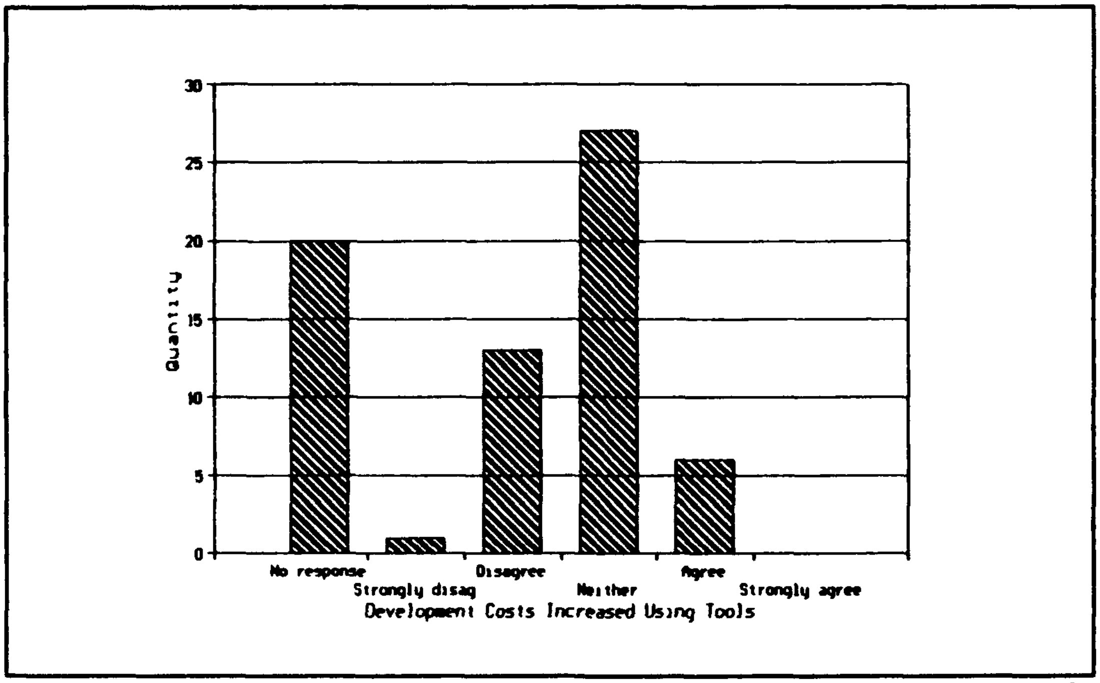

Figure G-18. Rating Whether Using CASE Tools Increased Development Costs in Sample Group

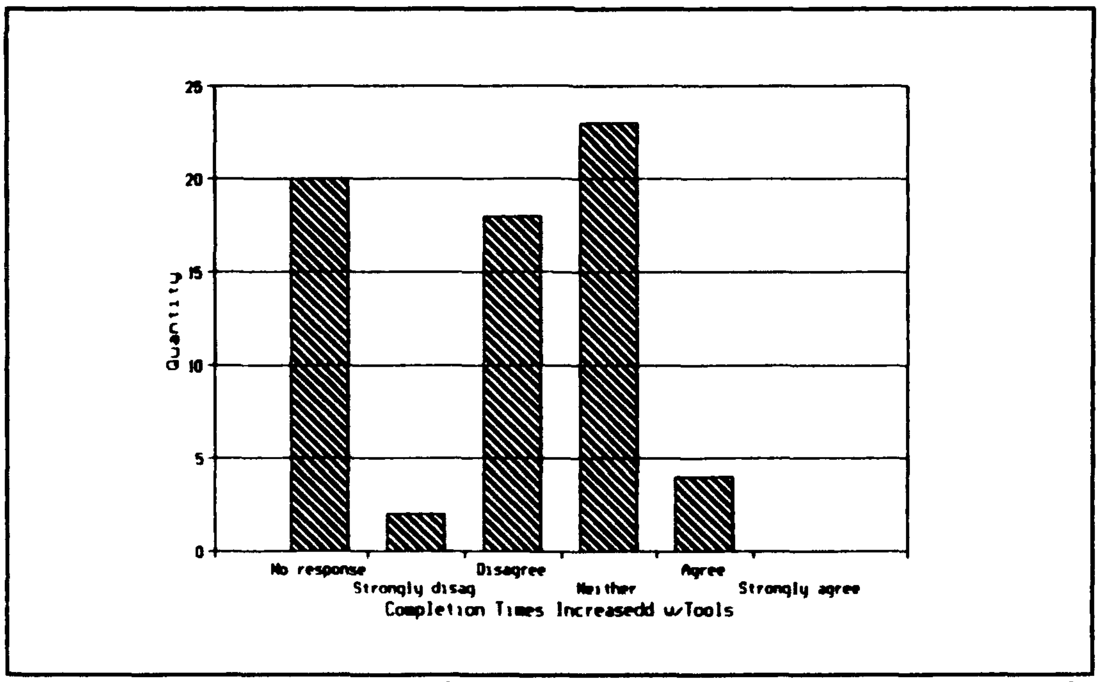

Figure G-19. Rating Whether Using CASE Tools Increased Time to Complete Projects in Sample Group

Appendix H - Frequency Distribution Charts of All Responses in Combination

Introduction

The following frequency distribution charts represent the answers provided by both the control group and the sample group. Of the 22 questions, questions 3, 9, and 18 were not graphed using a frequency distribution because respondents could provide multiple answers to these questions. Tables of the answers to these three questions can be found in Tables 4-7 through 4-9 in Chapter IV.

Frequency Distribution Charts

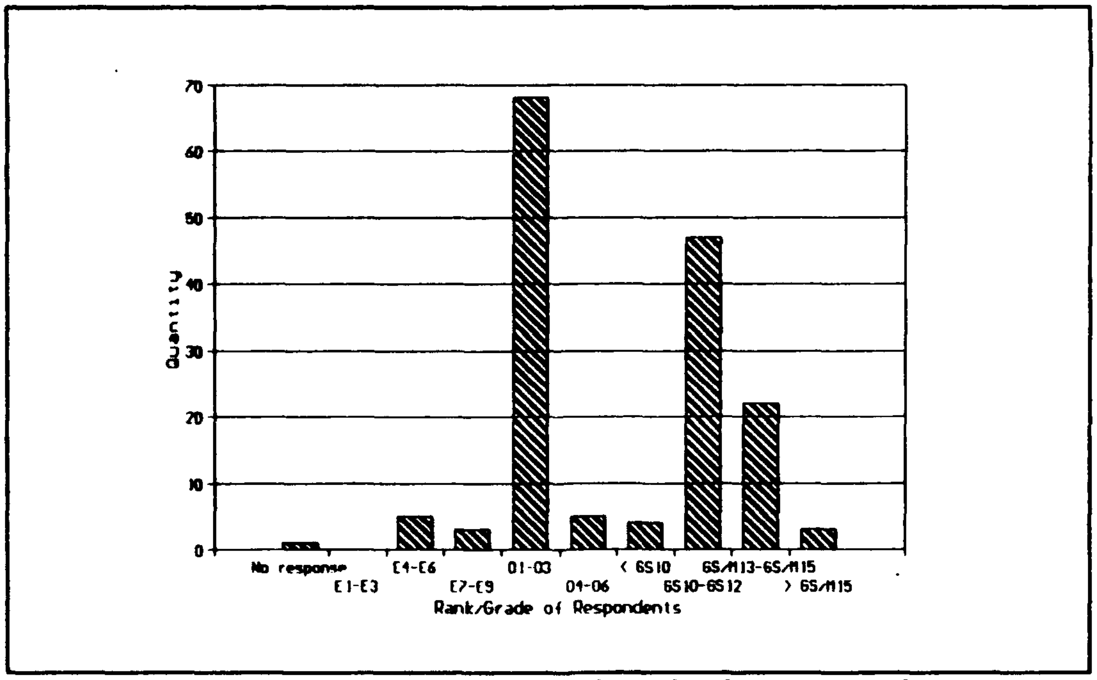

Figure H-1. Rank and Grade of All Respondents

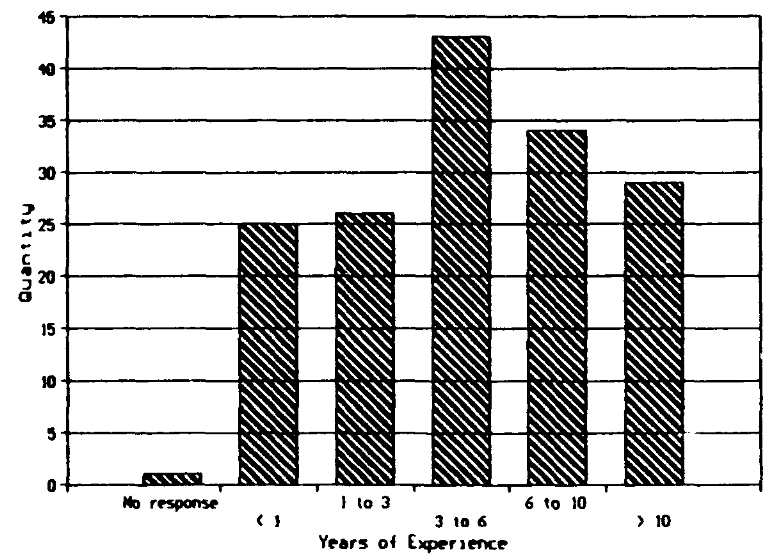

Figure H-2. Experience Levels of All Respondents

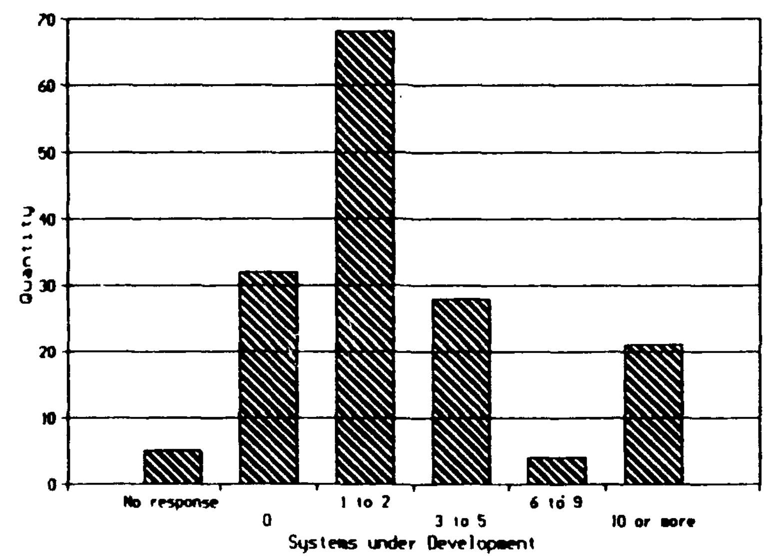

Figure H-3. Number of Systems in Development by All Surveyed Organizations

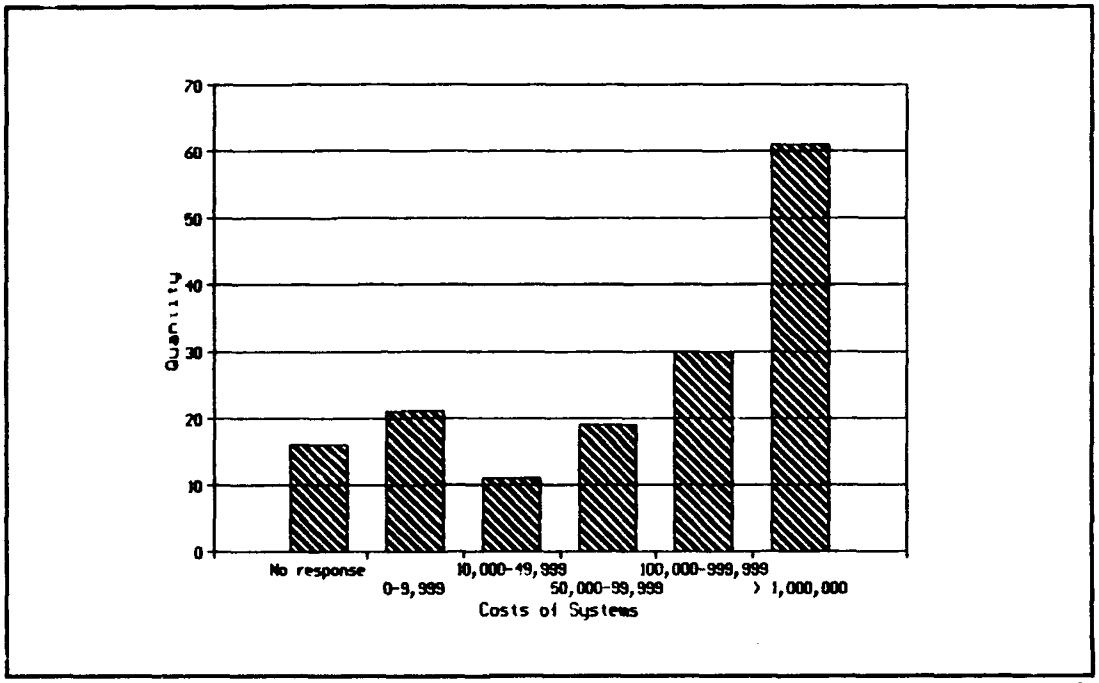

Figure H-4. Cost of Development Systems in All Surveyed Groups

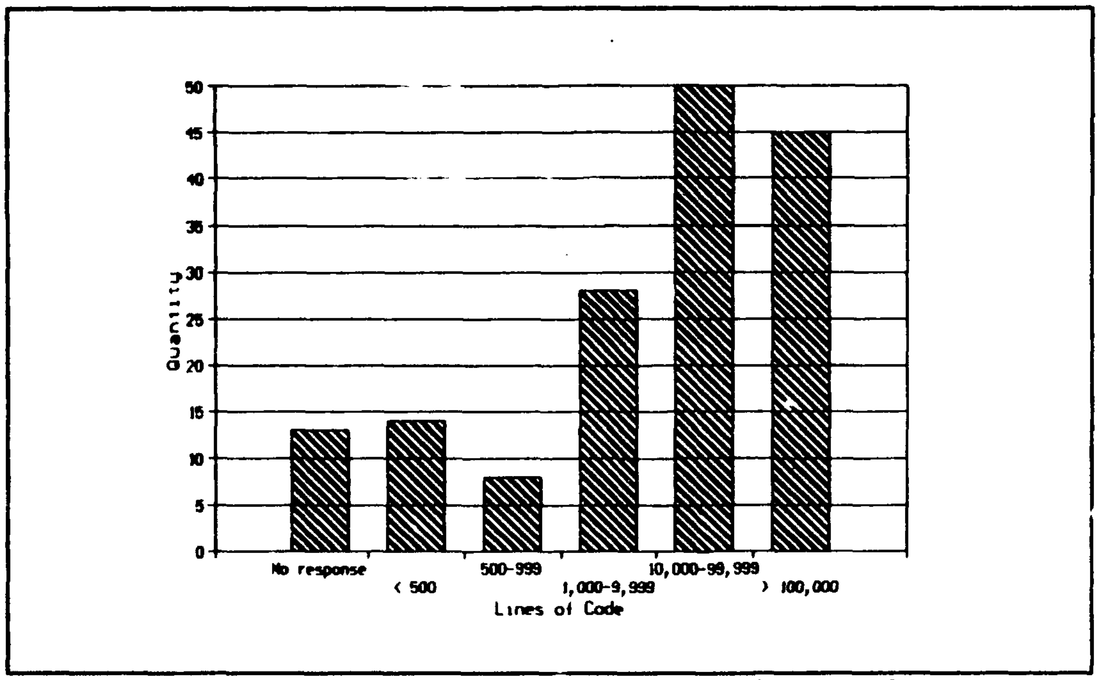

Figure H-5. Average Lines of Code in Development Systems in All Surveyed Organizations

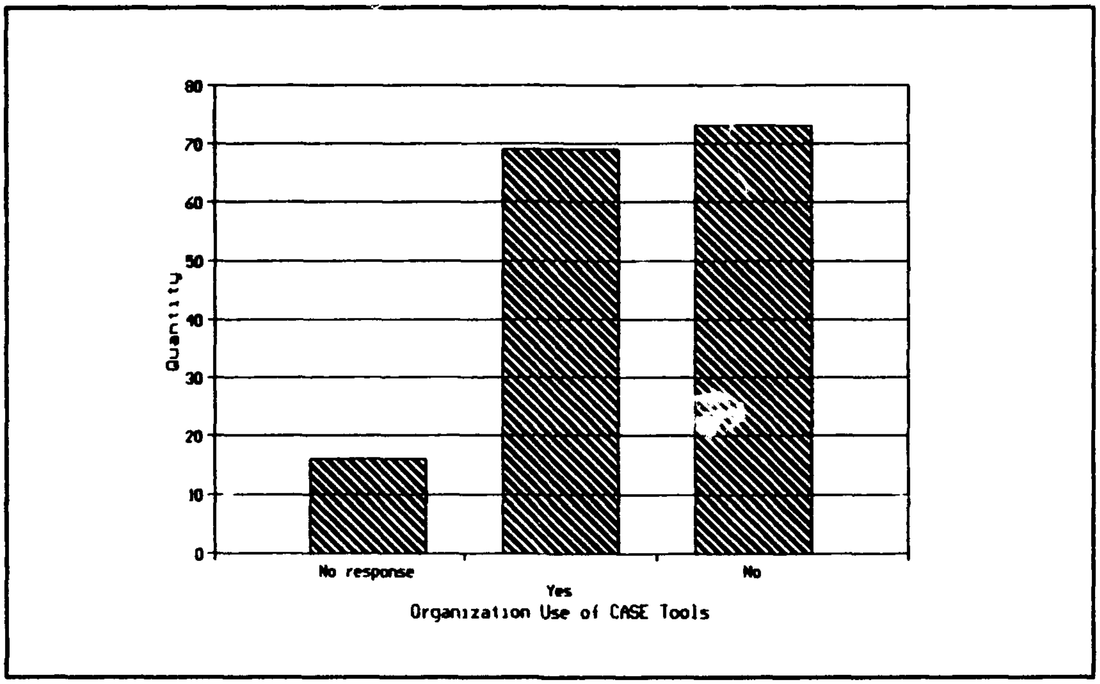

Figure H-6. Determining Number of Surveyed Organizations that Use Case Tools

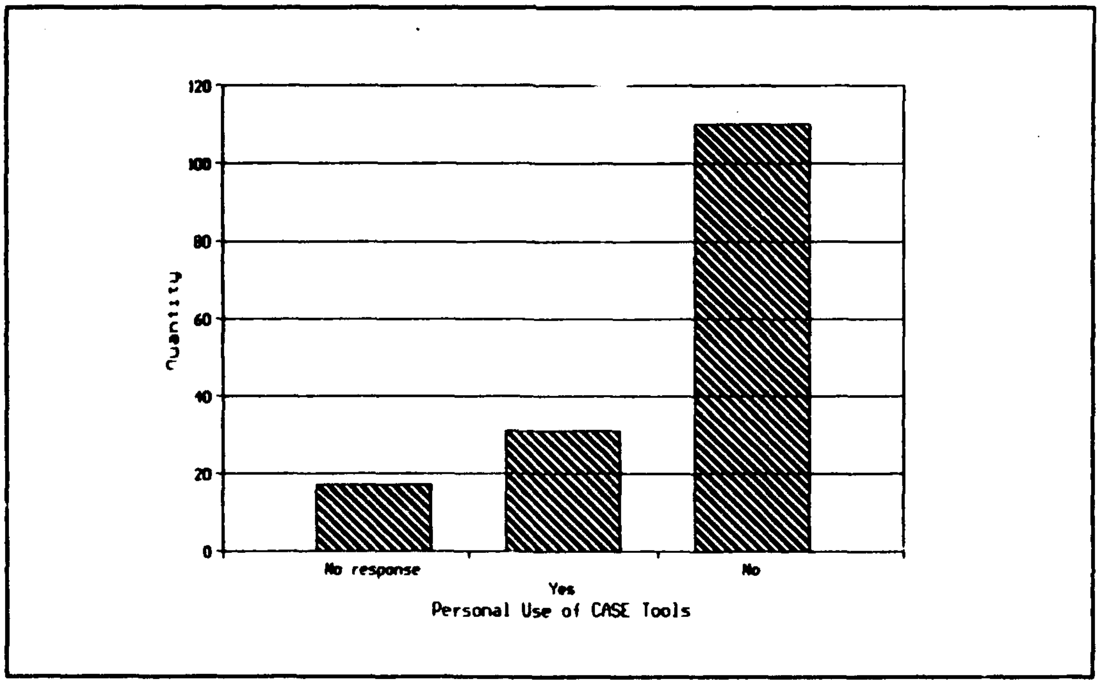

Figure H-7. Determining Number of Total Respondents that Use CASE Tools

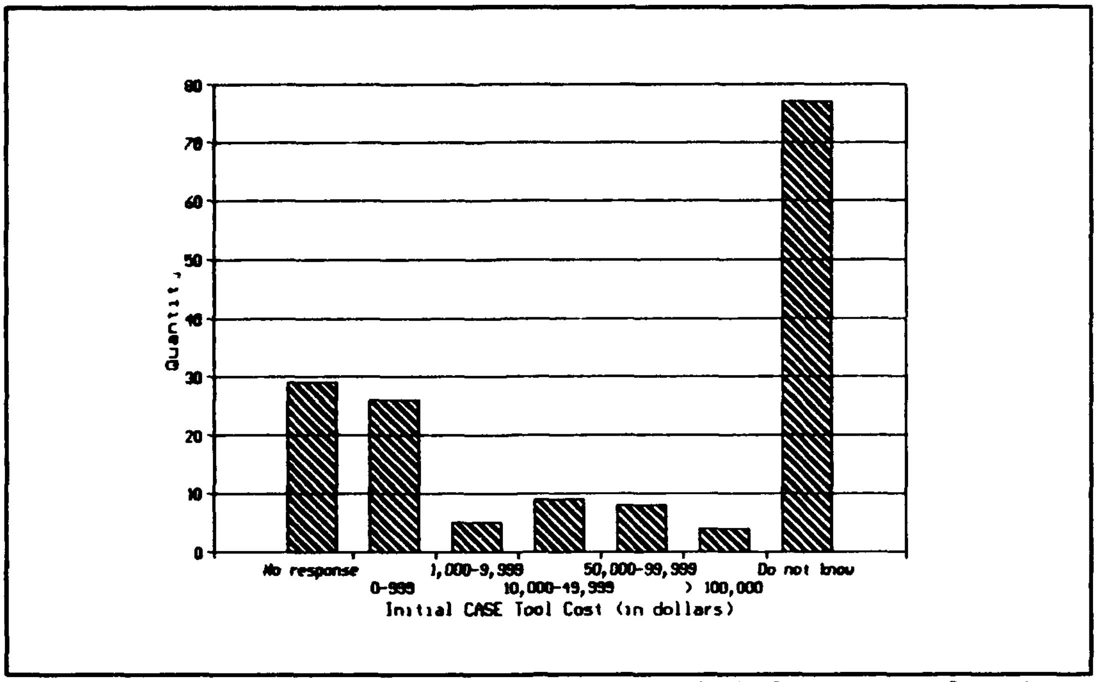

Figure H-8. Determining Average Initial Costs of Using CASE Tools in All Surveyed Organizations

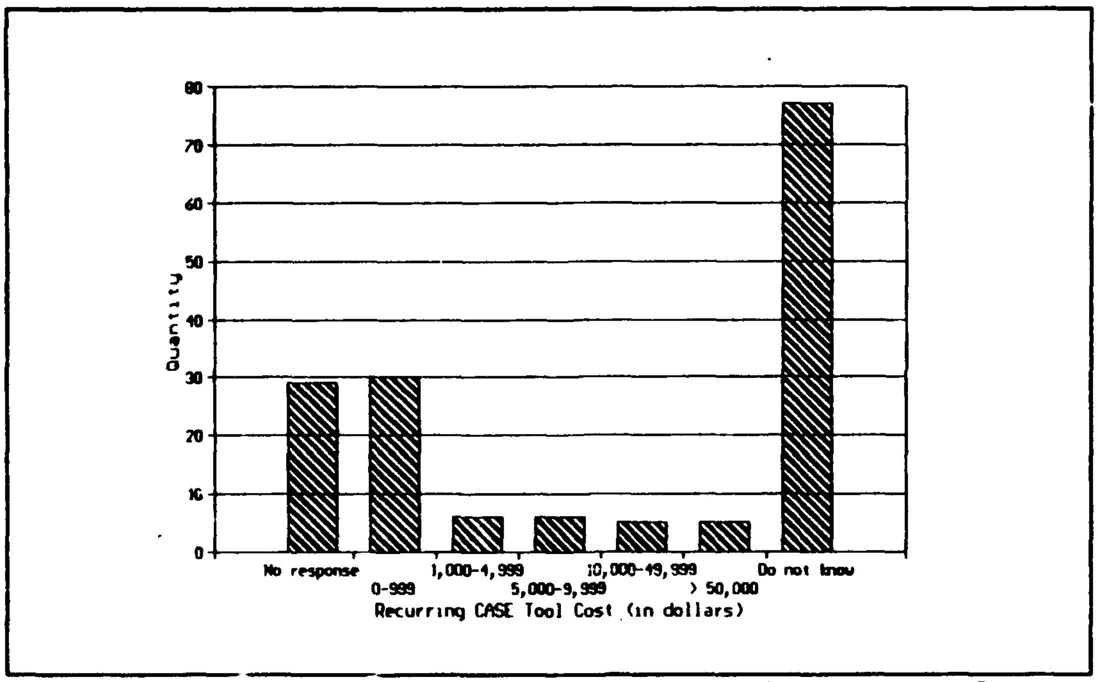

Figure H-9. Determining Average Recurring Costs of CASE Tool Use in All Surveyed Organizations

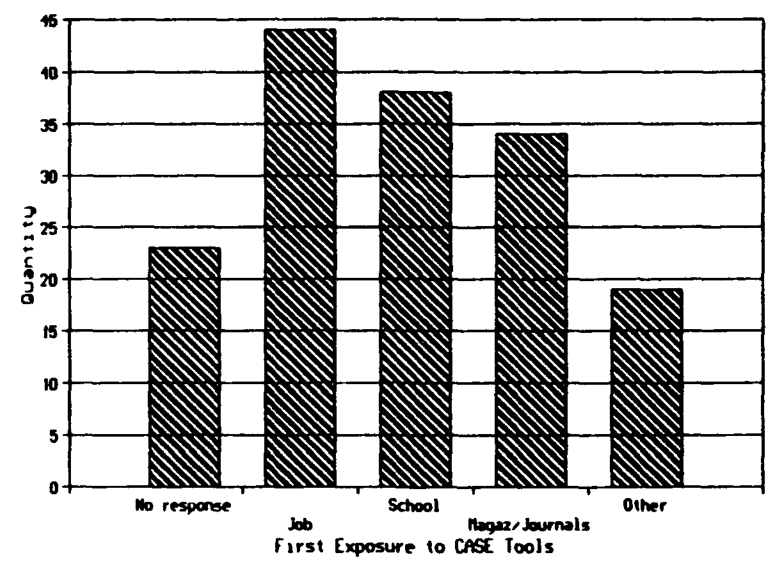

Figure H-10. Determining First Exposure to CASE Tools In All Respondents

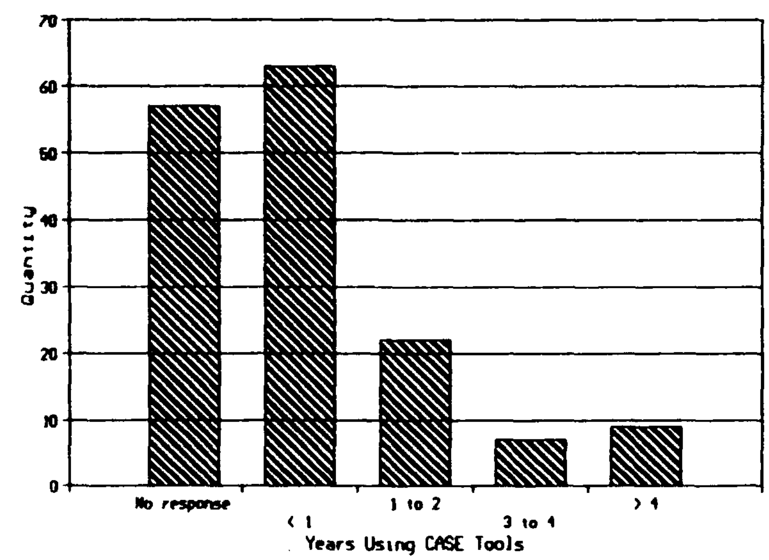

Figure H-11. Determining CASE Tool Experience Level of All Respondents

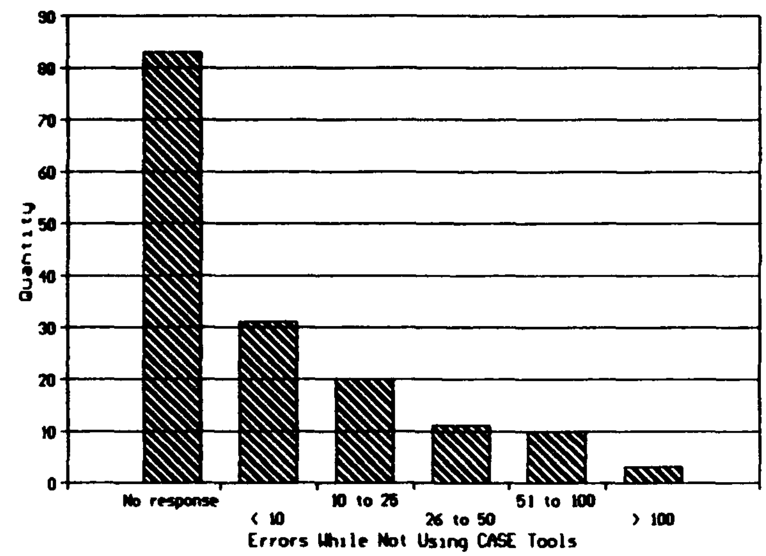

Figure H-12. Requirements Analysis Errors/KLOC of All Surveyed Organizations Not Using CASE Tools

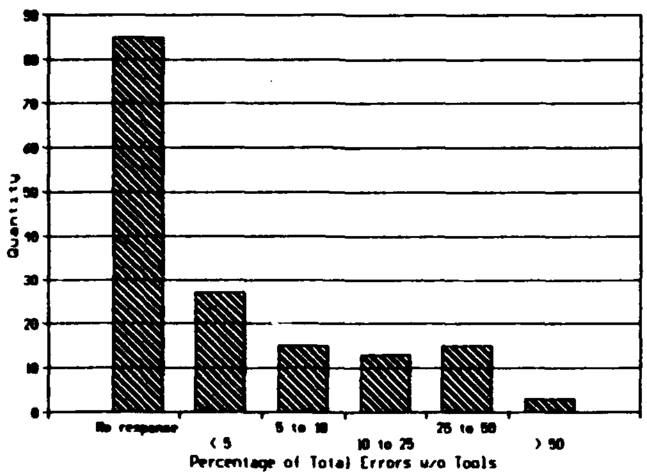

Figure H-13. Percentage of Total Errors Credited to Requirements Analysis in All Surveyed Organizations Not Using CASE Tools

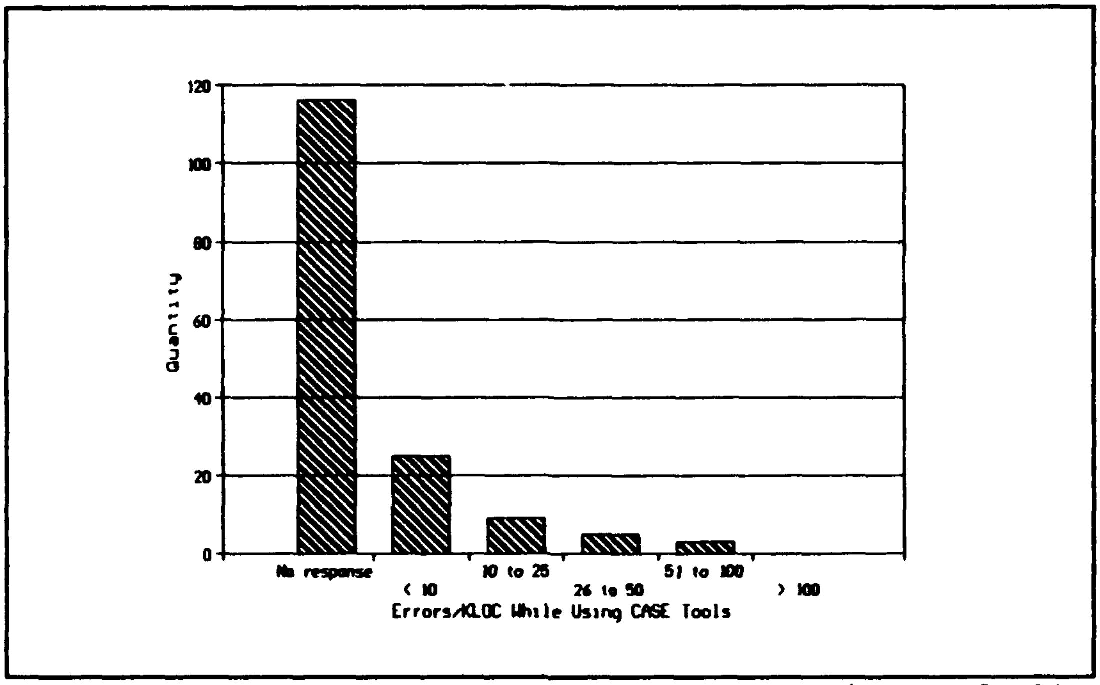

Figure H-14. Requirements Analysis Errors/KLOC of All Surveyed Organizations Using CASE Tools

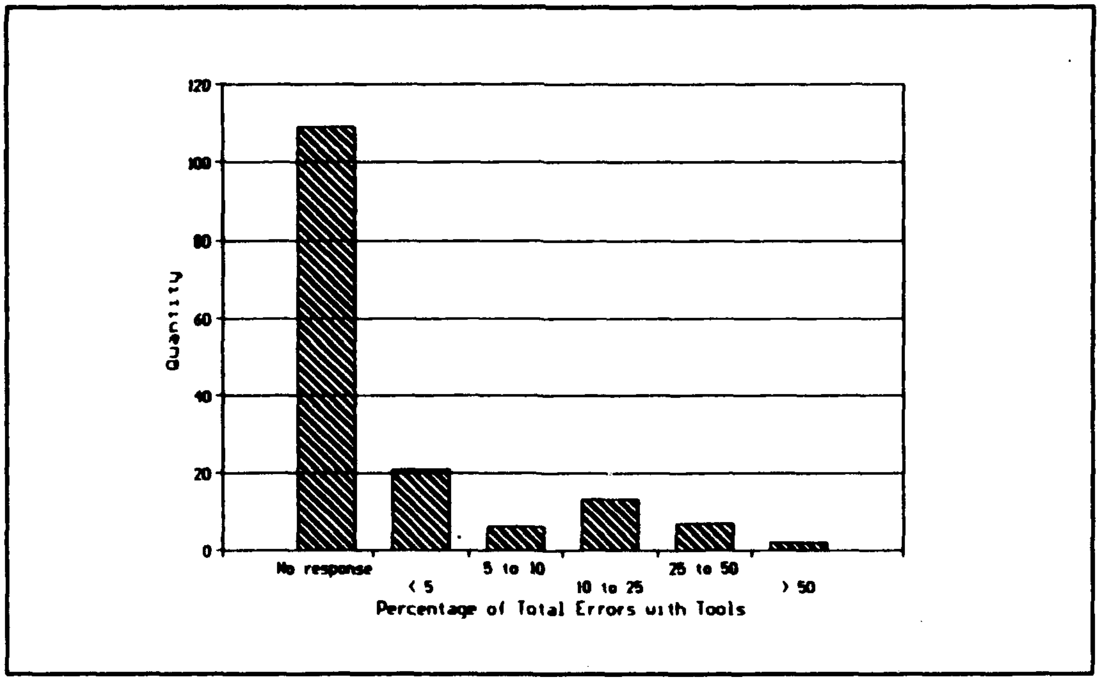

Figure H-15. Percentage of Total Errors Credited to Requirements Analysis in All Surveyed Organizations Using CASE Tools

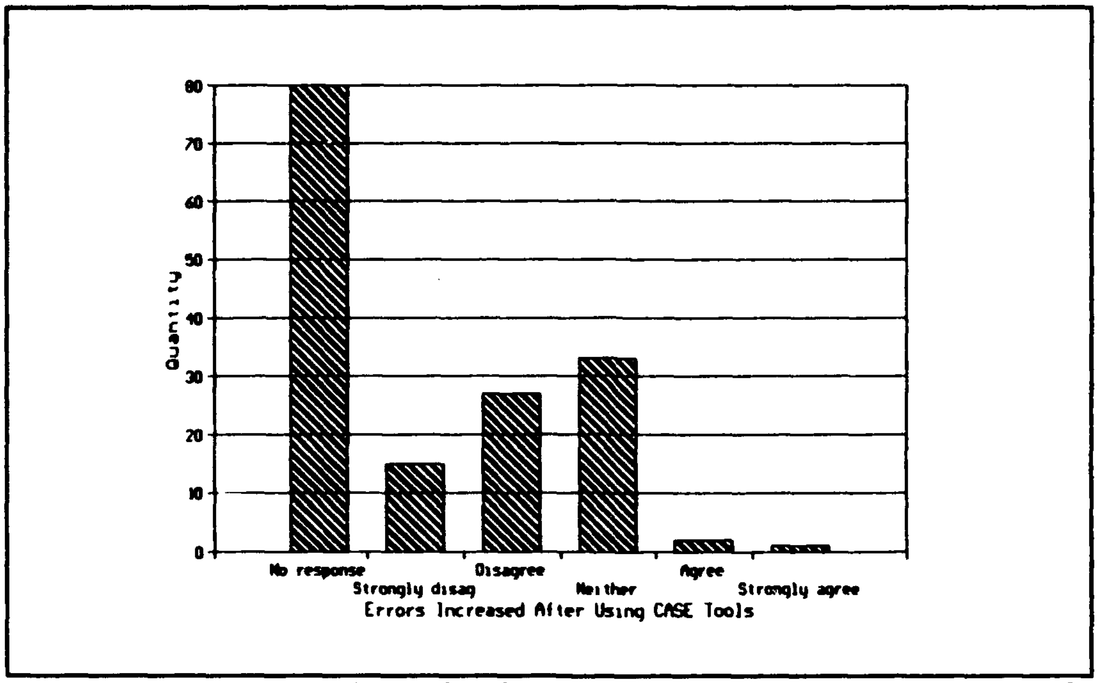

Figure H-16. Rating Whether Using CASE Tools Increased Error Rates in All Surveyed Organizations

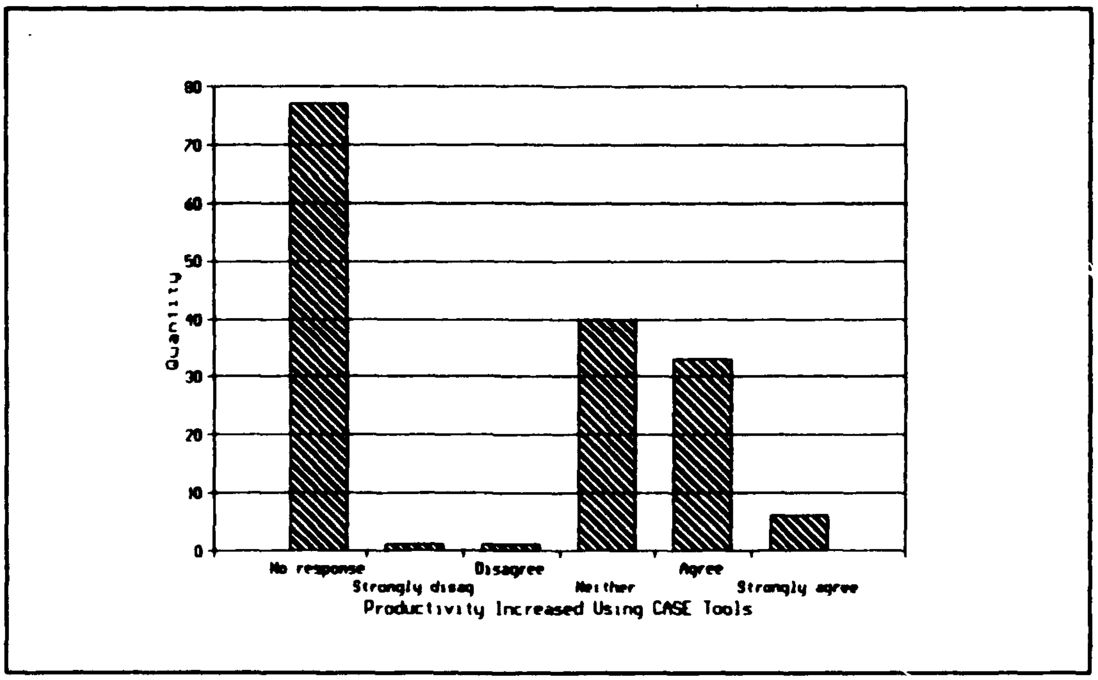

Figure H-17. Rating Whether Using CASE Tools Increased Productivity in All Surveyed Organizations

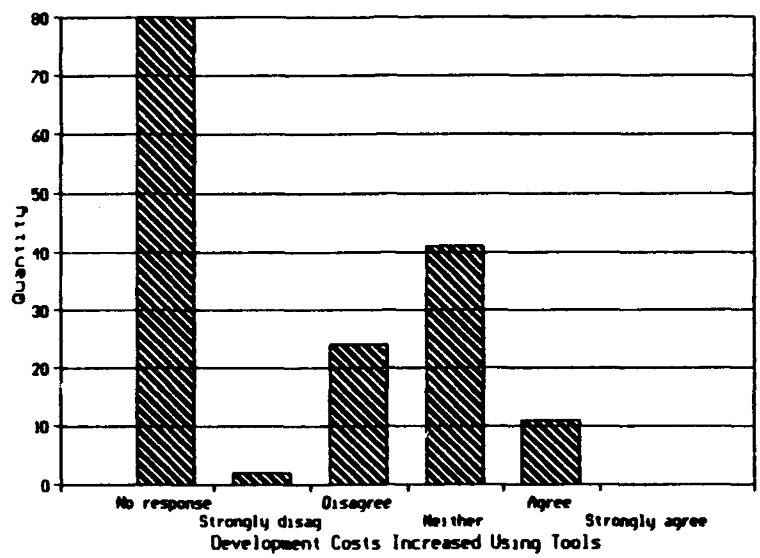

Figure H-18. Rating Whether Using CASE Tools Increased Development Costs in All Surveyed Organizations

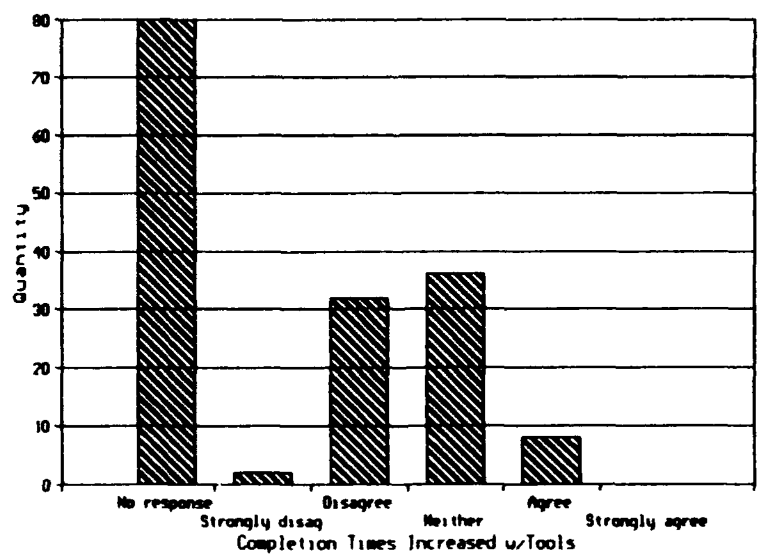

Figure H-19. Rating Whether Using CASE Tools Increased Time to Complete Projects in All Surveyed Organizations

Appendix I - SAS Analysis of Data

Introduction

The following tables are X x 2 contingency tables. The X represents the number of possible responses to the particular survey plus one. The one represents the possibility of having a response answer. The 2 in the formula represents the number of groups surveyed; the control group and the sample group. Also included in these tables are the Chi-Square calculations for each factor. The description and explanation of these tables, factors, and calculations are explained and analyzed in Chapter IV.

Tables and Chi-Square Calculations

Beginning on the next page, nineteen contingency tables (including Chi-Square calculations) are displayed. Questions 3, 9, and 18 were not included in the tables or Chi-Square calculations because of the respondents' ability to provide multiple answers to these specific questions. These tables and calculations were generated using the SAS Statistical program. 19 individual programs were created using the data compiled in Appendices E, G, and H as the inputs. Copies of these programs are not included in this document, but can be provided upon request.

Table I-1. Rank/Grade of Respondents

TABLE OF GRADE BY GROUP

GRADE	Frequency / Percent / Row Pct / Col Pct	CONT	SAMPLE	Total
<GS10	Frequency	3	1	4
	Percent	1.91	0.64	2.55
	Row Pct	75.00	25.00	
	Col Pct	3.33	1.49	
>GS15	Frequency	0	3	3
	Percent	0.00	1.91	1.91
	Row Pct	0.00	100.00	
	Col Pct	0.00	4.48	
EN4-6	Frequency	0	5	5
	Percent	0.00	3.18	3.18
	Row Pct	0.00	100.00	
	Col Pct	0.00	7.46	
EN7-9	Frequency	0	3	3
	Percent	0.00	1.91	1.91
	Row Pct	0.00	100.00	
	Col Pct	0.00	4.48	
GS10-12	Frequency	38	9	47
	Percent	24.20	5.73	29.94
	Row Pct	80.85	19.15	
	Col Pct	42.22	13.43	
GS13-15	Frequency	16	6	22
	Percent	10.19	3.82	14.01
	Row Pct	72.73	27.27	
	Col Pct	17.78	8.96	
O1-3	Frequency	31	37	68
	Percent	19.75	23.57	43.31
	Row Pct	45.59	54.41	
	Col Pct	34.44	55.22	
O4-6	Frequency	0	3	3
	Percent	0.00	1.91	1.91
	Row Pct	0.00	100.00	
	Col Pct	0.00	4.48	
OF4-6	Frequency	2	0	2
	Percent	1.27	0.00	1.27
	Row Pct	100.00	0.00	
	Col Pct	2.22	0.00	
Total		90	67	157
		57.32	42.68	100.00

RANK/GRADE OF RESPONDENTS

STATISTICS FOR TABLE OF GRADE BY GROUP

Statistic	DF	Value	Prob
Chi-Square	8	37.402	0.000
Likelihood Ratio Chi-Square	8	44.341	0.000
Mantel-Haenszel Chi-Square	1	0.240	0.624
Chi Coefficient		0.488	
Contingency Coefficient		0.439	
Cramer's V		0.488	

Sample Size = 157

WARNING: 67% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

Table I-2. Years of Experience of Respondents

TABLE OF YEARS BY GROUP

YEARS GROUP

YEARS	Frequency / Percent / Row Pct / Col Pct	CONT	SAMPLE	Total
1-3YRS	Frequency	15	11	26
	Percent	9.49	6.96	16.46
	Row Pct	57.69	42.31	
	Col Pct	16.48	16.42	
3-6YRS	Frequency	28	15	43
	Percent	17.72	9.49	27.22
	Row Pct	65.12	34.88	
	Col Pct	30.77	22.39	
6-10YRS	Frequency	20	14	34
	Percent	12.66	8.86	21.52
	Row Pct	58.82	41.18	
	Col Pct	21.98	20.90	
<1YR	Frequency	15	10	25
	Percent	9.49	6.33	15.82
	Row Pct	60.00	40.00	
	Col Pct	16.48	14.93	
>10YRS	Frequency	12	17	29
	Percent	7.59	10.76	18.35
	Row Pct	41.38	58.62	
	Col Pct	13.19	25.37	
NR	Frequency	1	0	1
	Percent	0.63	0.00	0.63
	Row Pct	100.00	0.00	
	Col Pct	1.10	0.00	
Total		91	67	158
		57.59	42.41	100.00

YEARS OF EXPERIENCE OF RESPONDENTS

STATISTICS FOR TABLE OF YEARS BY GROUP

Statistic	DF	Value	Prob
Chi-Square	5	4.935	0.424
Likelihood Ratio Chi-Square	5	5.274	0.383
Mantel-Haenszel Chi-Square	1	1.605	0.205

Table I-3. Number of Systems Under Development

TABLE OF NUMSYS BY GROUP

NUMSYS / Frequency / Percent / Row Pct / Col Pct	GROUP: CONT	SAMPLE	Total
0SYS	17 10.76 53.13 18.68	15 9.49 46.88 22.39	32 20.25
1-2SYS	31 19.62 45.59 34.07	37 23.42 54.41 55.22	68 43.04
10SYS	21 13.29 100.00 23.08	0 0.00 0.00 0.00	21 13.29
3-5SYS	16 10.13 57.14 17.58	12 7.59 42.86 17.91	28 17.72
6-9SYS	1 0.63 25.00 1.10	3 1.90 75.00 4.48	4 2.53
NR	5 3.16 100.00 5.49	0 0.00 0.00 0.00	5 3.16
Total	91 57.59	67 42.41	158 100.00

NUMBER OF SYSTEMS UNDER DEVELOPMENT

STATISTICS FOR TABLE OF NUMSYS BY GROUP

Statistic	DF	Value	Prob
Chi-Square	5	25.161	0.000
Likelihood Ratio Chi-Square	5	34.659	0.000
Mantel-Haenszel Chi-Square	1	3.587	0.058
Fisher's Exact Test (2-Tail)			7.12E-06
Phi Coefficient		0.399	
Contingency Coefficient		0.371	
Cramer's V		0.399	

Sample Size = 158

WARNING: 33% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

Table I-4. Cost of Systems Under Development

TABLE OF COST BY GROUP

COST GROUP

Frequency / Expected / Percent / Row Pct / Col Pct	CONT	SAMPLE	Total
1M	42 35.133 26.58 68.85 46.15	19 25.867 12.03 31.15 28.36	61 38.61
49.9K	3 6.3354 1.90 27.27 3.30	8 4.6646 5.06 72.73 11.94	11 6.96
9.9K	8 12.095 5.06 38.10 8.79	13 8.9051 8.23 61.90 19.40	21 13.29
99.9K	7 10.943 4.43 36.84 7.69	12 8.057 7.59 63.16 17.91	19 12.03
999.9K	15 17.278 9.49 50.00 16.48	15 12.722 9.49 50.00 22.39	30 18.99
NR	16 9.2152 10.13 100.00 17.58	0 6.7848 0.00 0.00 0.00	16 10.13
Total	91 57.59	67 42.41	158 100.00

COST OF SYSTEMS UNDER DEVELOPMENT

STATISTICS FOR TABLE OF COST BY GROUP

Statistic	DF	Value	Prob
Chi-Square	5	26.415	0.000
Likelihood Ratio Chi-Square	5	32.303	0.000
Mantel-Haenszel Chi-Square	1	0.016	0.899
Phi Coefficient		0.409	
Contingency Coefficient		0.378	
Cramer's V		0.409	

Sample Size = 158

Table I-5. Lines of Code in Systems Under Development

TABLE OF LOC BY GROUP

LOC	GROUP		
Frequency / Expected / Percent / Row Pct / Col Pct	CONT	SAMPLE	Total
.999K	4 4.6076 2.53 50.00 4.40	4 3.3924 2.53 50.00 5.97	8 5.06
1M	30 25.918 18.99 66.67 32.97	15 19.082 9.49 33.33 22.39	45 28.48
9.9K	14 16.127 8.86 50.00 15.38	14 11.873 8.86 50.00 20.90	28 17.72
99.9K	21 28.797 13.29 42.00 23.08	29 21.203 18.35 58.00 43.28	50 31.65
>500	10 8.0633 6.33 71.43 10.99	4 5.9367 2.53 28.57 5.97	14 8.86
NR	12 7.4873 7.59 92.31 13.19	1 5.5127 0.63 7.69 1.49	13 8.23
Total	91 57.59	67 42.41	158 100.00

LINES OF CODE IN SYSTEMS UNDER DEVELOPMENT

STATISTICS FOR TABLE OF LOC BY GROUP

Statistic	DF	Value	Prob
Chi-Square	5	14.856	0.011
Likelihood Ratio Chi-Square	5	16.350	0.006
Mantel-Haenszel Chi-Square	1	0.661	0.416
Phi Coefficient		0.307	
Contingency Coefficient		0.293	
Cramer's V		0.307	

Sample Size = 158

Table I-6. Organizational Use of CASE Tools

TABLE OF ORGUSE BY GROUP

ORGUSE (Frequency / Expected / Percent / Row Pct / Col Pct)	GROUP: CONT	GROUP: SAMPLE	Total
NO	41 42.044 25.95 56.16 45.05	32 30.956 20.25 43.84 47.76	73 46.20
NR	16 9.2152 10.13 100.00 17.58	0 6.7848 0.00 0.00 0.00	16 10.13
YES	34 39.741 21.52 49.28 37.36	35 29.259 22.15 50.72 52.24	69 43.67
Total	91 57.59	67 42.41	158 100.00

STATISTICS FOR TABLE OF ORGUSE BY GROUP

Statistic	DF	Value	Prob
Chi-Square	2	13.797	0.001
Likelihood Ratio Chi-Square	2	19.648	0.000
Mantel-Haenszel Chi-Square	1	0.632	0.426
Phi Coefficient		0.296	
Contingency Coefficient		0.283	
Cramer's V		0.296	

Sample Size = 158

Table I-7. Personal Use of CASE Tools

TABLE OF ORGUSE BY GROUP

ORGUSE (Frequency / Expected / Percent / Row Pct / Col Pct)	GROUP: CONT	GROUP: SAMPLE	Total
NO	41 42.044 25.95 56.16 45.05	32 30.956 20.25 43.84 47.76	73 46.20
NR	16 9.2152 10.13 100.00 17.58	0 6.7848 0.00 0.00 0.00	16 10.13
YES	34 39.741 21.52 49.28 37.36	35 29.259 22.15 50.72 52.24	69 43.67
Total	91 57.59	67 42.41	158 100.00

STATISTICS FOR TABLE OF ORGUSE BY GROUP

Statistic	DF	Value	Prob
Chi-Square	2	13.797	0.001
Likelihood Ratio Chi-Square	2	19.648	0.000
Mantel-Haenszel Chi-Square	1	0.632	0.426
Phi Coefficient		0.296	
Contingency Coefficient		0.283	
Cramer's V		0.296	

Sample Size = 158

Table I-8. Initial Cost of Using CASE Tools

TABLE OF INITCOST BY GROUP

INITCOST (Frequency / Expected / Percent / Row Pct / Col Pct)	GROUP: CONT	GROUP: SAMPLE	Total
.999K	15 14.975 9.49 57.69 16.48	11 11.025 6.96 42.31 16.42	26 16.46
100K	2 2.3038 1.27 50.00 2.20	2 1.6962 1.27 50.00 2.99	4 2.53
49.9K	4 5.1835 2.53 44.44 4.40	5 3.8165 3.16 55.56 7.46	9 5.70
9.9K	1 2.8797 0.63 20.00 1.10	4 2.1203 2.53 80.00 5.97	5 3.16
99.9K	6 4.6076 3.80 75.00 6.59	2 3.3924 1.27 25.00 2.99	8 5.06
NOTKNOW	43 44.348 27.22 55.84 47.25	34 32.652 21.52 44.16 50.75	77 48.73
NR	20 16.703 12.66 68.97 21.98	9 12.297 5.70 31.03 13.43	29 18.35
Total	91 57.59	67 42.41	158 100.00

INITIAL COST OF USING CASE TOOLS

STATISTICS FOR TABLE OF INITCOST BY GROUP

Statistic	DF	Value	Prob
Chi-Square	6	6.249	0.396
Likelihood Ratio Chi-Square	6	6.423	0.378
Mantel-Haenszel Chi-Square	1	0.630	0.427
Phi Coefficient		0.199	
Contingency Coefficient		0.195	
Cramer's V		0.199	

Sample Size = 158

WARNING: 50% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

Table I-9. Recurring Cost of Using CASE Tools

TABLE OF RECCOST BY GROUP

RECCOST (Frequency / Expected / Percent / Row Pct / Col Pct)	GROUP: CONT	GROUP: SAMPLE	Total
.999K	17 17.278 10.76 56.67 18.68	13 12.722 8.23 43.33 19.40	30 18.99
4.9K	3 3.4557 1.90 50.00 3.30	3 2.5443 1.90 50.00 4.48	6 3.80
49.9K	1 2.8797 0.63 20.00 1.10	4 2.1203 2.53 80.00 5.97	5 3.16
50K	2 2.8797 1.27 40.00 2.20	3 2.1203 1.90 60.00 4.48	5 3.16
9.9K	2 3.4557 1.27 33.33 2.20	4 2.5443 2.53 66.67 5.97	6 3.80
NOTKNOW	44 44.348 27.85 57.14 48.35	33 32.652 20.89 42.86 49.25	77 48.73
NR	22 16.703 13.92 75.86 24.18	7 12.297 4.43 24.14 10.45	29 18.35
Total	91 57.59	67 42.41	158 100.00

RECURRING COST OF USING CASE TOOLS

STATISTICS FOR TABLE OF RECCOST BY GROUP

Statistic	DF	Value	Prob
Chi-Square	6	9.094	0.168
Likelihood Ratio Chi-Square	6	9.408	0.152
Mantel-Haenszel Chi-Square	1	1.636	0.201
Phi Coefficient		0.240	
Contingency Coefficient		0.233	
Cramer's V		0.240	

Sample Size = 158

WARNING: 57% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

Table I-10. First Exposure to CASE Tools

TABLE OF EXPOSE BY GROUP

EXPOSE / GROUP Frequency Expected Percent Row Pct Col Pct	CONT	SAMPLE	Total
JOB	21 25.342 13.29 47.73 23.08	23 18.658 14.56 52.27 34.33	44 27.85
MAG/JOUR	23 19.582 14.56 67.65 25.27	11 14.418 6.96 32.35 16.42	34 21.52
NR	19 13.247 12.03 82.61 20.88	4 9.7532 2.53 17.39 5.97	23 14.56
OTHER	12 10.943 7.59 63.16 13.19	7 8.057 4.43 36.84 10.45	19 12.03
SCHOOL	16 21.886 10.13 42.11 17.58	22 16.114 13.92 57.89 32.84	38 24.05
Total	91 57.59	67 42.41	158 100.00

FIRST EXPOSURE TO CASE TOOLS

STATISTICS FOR TABLE OF EXPOSE BY GROUP

Statistic	DF	Value	Prob
Chi-Square	4	13.027	0.011
Likelihood Ratio Chi-Square	4	13.673	0.008
Mantel-Haenszel Chi-Square	1	0.321	0.571
Phi Coefficient		0.287	
Contingency Coefficient		0.276	
Cramer's V		0.287	

Sample Size = 158

Table I-11. Length (Years) Using CASE Tools

TABLE OF LENGTH BY GROUP

LENGTH GROUP

Frequency / Expected / Percent / Row Pct / Col Pct	CONT	SAMPLE	Total
1-2YRS	8 12.671 5.06 36.36 8.79	14 9.3291 8.86 63.64 20.90	22 13.92
3-4YRS	3 4.0316 1.90 42.86 3.30	4 2.9684 2.53 57.14 5.97	7 4.43
<1YR	31 36.285 19.62 49.21 34.07	32 26.715 20.25 50.79 47.76	63 39.87
>4YRS	5 5.1835 3.16 55.56 5.49	4 3.8165 2.53 44.44 5.97	9 5.70
NR	44 32.829 27.85 77.19 48.35	13 24.171 8.23 22.81 19.40	57 36.08
Total	91 57.59	67 42.41	158 100.00

LENGTH (YEARS) USING CASE TOOLS

STATISTICS FOR TABLE OF LENGTH BY GROUP

Statistic	DF	Value	Prob
Chi-Square	4	15.477	0.004
Likelihood Ratio Chi-Square	4	16.076	0.003
Mantel-Haenszel Chi-Square	1	14.391	0.000
Phi Coefficient		0.313	
Contingency Coefficient		0.299	
Cramer's V		0.313	

Sample Size = 158

WARNING: 30% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

Table I-12. Errors/KLOC w/o Using CASE Tools

TABLE OF NUMKLOC BY GROUP

NUMKLOC / Frequency / Expected / Percent / Row Pct / Col Pct	GROUP: CONT	SAMPLE	Total
10-25E	6 11.519 3.80 30.00 6.59	14 8.481 8.86 70.00 20.90	20 12.66
26-50E	4 6.3354 2.53 36.36 4.40	7 4.6646 4.43 63.64 10.45	11 6.96
51-100E	3 5.7595 1.90 30.00 3.30	7 4.2405 4.43 70.00 10.45	10 6.33
<10E	13 17.854 8.23 41.94 14.29	18 13.146 11.39 58.06 26.87	31 19.62
>100E	2 1.7278 1.27 66.67 2.20	1 1.2722 0.63 33.33 1.49	3 1.90
NR	63 47.804 39.87 75.90 69.23	20 35.196 12.66 24.10 29.85	83 52.53
Total	91 57.59	67 42.41	158 100.00

ERRORS/KLOC W/O USING CASE TOOLS

STATISTICS FOR TABLE OF NUMKLOC BY GROUP

Statistic	DF	Value	Prob
Chi-Square	5	25.989	0.000
Likelihood Ratio Chi-Square	5	26.655	0.000
Mantel-Haenszel Chi-Square	1	22.865	0.000
Phi Coefficient		0.406	
Contingency Coefficient		0.376	
Cramer's V		0.406	

Sample Size = 158

WARNING: 33% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

Table I-13. Percentage of Errors Credited to Req Anal w/o CASE Tools

TABLE OF PERERR BY GROUP

PERERR / GROUP (Frequency, Expected, Percent, Row Pct, Col Pct)	CONT	SAMPLE	Total
10-25%	5 7.4873 3.16 38.46 5.49	8 5.5127 5.06 61.54 11.94	13 8.23
25-50%	7 8.6392 4.43 46.67 7.69	8 6.3608 5.06 53.33 11.94	15 9.49
5-10%	3 8.6392 1.90 20.00 3.30	12 6.3608 7.59 80.00 17.91	15 9.49
<5%	12 15.551 7.59 44.44 13.19	15 11.449 9.49 55.56 22.39	27 17.09
>50%	1 1.7278 0.63 33.33 1.10	2 1.2722 1.27 66.67 2.99	3 1.90
NR	63 48.956 39.87 74.12 69.23	22 36.044 13.92 25.88 32.84	85 53.80
Total	91 57.59	67 42.41	158 100.00

PERCENTAGE OF ERRORS CREDITED TO REQ ANAL W/O CASE TOOLS

STATISTICS FOR TABLE OF PERERR BY GROUP

Statistic	DF	Value	Prob
Chi-Square	5	23.499	0.000
Likelihood Ratio Chi-Square	5	24.187	0.000
Mantel-Haenszel Chi-Square	1	16.054	0.000
Phi Coefficient		0.386	
Contingency Coefficient		0.360	
Cramer's V		0.386	

Sample Size = 158

Table I-14. Errors/KLOC Using CASE Tools

TABLE OF NUMKLOC BY GROUP

NUMKLOC GROUP

Frequency / Expected / Percent / Row Pct / Col Pct	CONT	SAMPLE	Total
10-25E	2 5.1835 1.27 22.22 2.20	7 3.8165 4.43 77.78 10.45	9 5.70
26-50E	2 2.8797 1.27 40.00 2.20	3 2.1203 1.90 60.00 4.48	5 3.16
51-100E	1 1.7278 0.63 33.33 1.10	2 1.2722 1.27 66.67 2.99	3 1.90
<10E	5 14.399 3.16 20.00 5.49	20 10.601 12.66 80.00 29.85	25 15.82
NR	81 66.81 51.27 69.83 89.01	35 49.19 22.15 30.17 52.24	116 73.42
Total	91 57.59	67 42.41	158 100.00

ERRORS/KLOC USING CASE TOOLS

STATISTICS FOR TABLE OF NUMKLOC BY GROUP

Statistic	DF	Value	Prob
Chi-Square	4	27.542	0.000
Likelihood Ratio Chi-Square	4	28.213	0.000
Mantel-Haenszel Chi-Square	1	15.257	0.000
Phi Coefficient		0.418	
Contingency Coefficient		0.385	
Cramer's V		0.418	

Sample Size = 158

WARNING: 50% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

Table I-15. Percentage of Errors Credited to Req Anal with CASE Tools

TABLE OF PERERR BY GROUP

PERERR / Frequency / Expected / Percent / Row Pct / Col Pct	GROUP: CONT	GROUP: SAMPLE	Total
10-25%	4 7.4873 2.53 30.77 4.40	9 5.5127 5.70 69.23 13.43	13 8.23
25-50%	4 4.0316 2.53 57.14 4.40	3 2.9684 1.90 42.86 4.48	7 4.43
5-10%	1 3.4557 0.63 16.67 1.10	5 2.5443 3.16 83.33 7.46	6 3.80
<5%	4 12.095 2.53 19.05 4.40	17 8.9051 10.76 80.95 25.37	21 13.29
>50%	0 1.1519 0.00 0.00 0.00	2 0.8481 1.27 100.00 2.99	2 1.27
NR	78 62.778 49.37 71.56 85.71	31 46.222 19.62 28.44 46.27	109 68.99
Total	91 57.59	67 42.41	158 100.00

PERCENTAGE OF ERRORS CREDITED TO REQ ANAL WITH CASE TOOLS

STATISTICS FOR TABLE OF PERERR BY GROUP

Statistic	DF	Value	Prob
Chi-Square	5	32.142	0.000
Likelihood Ratio Chi-Square	5	33.749	0.000
Mantel-Haenszel Chi-Square	1	17.109	0.000
Phi Coefficient		0.451	
Contingency Coefficient		0.411	
Cramer's V		0.451	

Sample Size = 158

WARNING: 50% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

Table I-16. Errors Increased with Using CASE Tools

TABLE OF COMMENT BY GROUP

COMMENT GROUP

Frequency / Expected / Percent / Row Pct / Col Pct	CONT	SAMPLE	Total
AGREE	2 1.1519 1.27 100.00 2.20	0 0.8481 0.00 0.00 0.00	2 1.27
DISAGREE	11 15.551 6.96 40.74 12.09	16 11.449 10.13 59.26 23.88	27 17.09
NEITHER	10 19.006 6.33 30.30 10.99	23 13.994 14.56 69.70 34.33	33 20.89
NR	60 46.076 37.97 75.00 65.93	20 33.924 12.66 25.00 29.85	80 50.63
STRAGREE	0 0.5759 0.00 0.00 0.00	1 0.4241 0.63 100.00 1.49	1 0.63
STRDISAG	8 8.6392 5.06 53.33 8.79	7 6.3608 4.43 46.67 10.45	15 9.49
Total	91 57.59	67 42.41	158 100.00

ERRORS INCREASED WITH USING CASE TOOLS

STATISTICS FOR TABLE OF COMMENT BY GROUP

Statistic	DF	Value	Prob
Chi-Square	5	26.070	0.000
Likelihood Ratio Chi-Square	5	27.690	0.000
Mantel-Haenszel Chi-Square	1	3.908	0.048
Phi Coefficient		0.406	
Contingency Coefficient		0.376	
Cramer's V		0.406	

Sample Size = 158

WARNING: 33% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

Table I-17. Productivity Increased with Using CASE Tools

TABLE OF COMMENT BY GROUP

COMMENT GROUP

Frequency / Expected / Percent / Row Pct / Col Pct

COMMENT		CONT	SAMPLE	Total
AGREE	Frequency	18	15	33
	Expected	19.006	13.994	
	Percent	11.39	9.49	20.89
	Row Pct	54.55	45.45	
	Col Pct	19.78	22.39	
DISAGREE	Frequency	1	0	1
	Expected	0.5759	0.4241	
	Percent	0.63	0.00	0.63
	Row Pct	100.00	0.00	
	Col Pct	1.10	0.00	
NEITHER	Frequency	13	27	40
	Expected	23.038	16.962	
	Percent	8.23	17.09	25.32
	Row Pct	32.50	67.50	
	Col Pct	14.29	40.30	
NR	Frequency	59	18	77
	Expected	44.348	32.652	
	Percent	37.34	11.39	48.73
	Row Pct	76.62	23.38	
	Col Pct	64.84	26.87	
STRAGREE	Frequency	0	6	6
	Expected	3.4557	2.5443	
	Percent	0.00	3.80	3.80
	Row Pct	0.00	100.00	
	Col Pct	0.00	8.96	
STRDISAG	Frequency	0	1	1
	Expected	0.5759	0.4241	
	Percent	0.00	0.63	0.63
	Row Pct	0.00	100.00	
	Col Pct	0.00	1.49	
Total		91	67	158
		57.59	42.41	100.00

PRODUCTIVITY INCREASED WITH USING CASE TOOLS

STATISTICS FOR TABLE OF COMMENT BY GROUP

Statistic	DF	Value	Prob
Chi-Square	5	32.099	0.000
Likelihood Ratio Chi-Square	5	35.710	0.000
Mantel-Haenszel Chi-Square	1	0.983	0.321
Phi Coefficient		0.451	
Contingency Coefficient		0.411	
Cramer's V		0.451	

Sample Size = 158

WARNING: 50% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

Table I-18. Development Costs Increased Using CASE Tools

TABLE OF COMMENT BY GROUP

COMMENT / GROUP (Frequency, Expected, Percent, Row Pct, Col Pct)	CONT	SAMPLE	Total
AGREE	5 6.3354 3.16 45.45 5.49	6 4.6646 3.80 54.55 8.96	11 6.96
DISAGREE	11 13.823 6.96 45.83 12.09	13 10.177 8.23 54.17 19.40	24 15.19
NEITHER	14 23.614 8.86 34.15 15.38	27 17.386 17.09 65.85 40.30	41 25.95
NR	60 46.076 37.97 75.00 65.93	20 33.924 12.66 25.00 29.85	80 50.63
STRDISAG	1 1.1519 0.63 50.00 1.10	1 0.8481 0.63 50.00 1.49	2 1.27
Total	91 57.59	67 42.41	158 100.00

DEVELOPMENT COSTS INCREASED WITH USING CASE TOOLS

STATISTICS FOR TABLE OF COMMENT BY GROUP

Statistic	DF	Value	Prob
Chi-Square	4	21.224	0.000
Likelihood Ratio Chi-Square	4	21.722	0.000
Mantel-Haenszel Chi-Square	1	10.121	0.001
Phi Coefficient		0.367	
Contingency Coefficient		0.344	
Cramer's V		0.367	

Sample Size = 158

WARNING: 30% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

Table I-19. Project Completion Time Increased Using CASE Tools

TABLE OF COMMENT BY GROUP

COMMENT / Frequency / Expected / Percent / Row Pct / Col Pct	GROUP: CONT	SAMPLE	Total
AGREE	4 4.6076 2.53 50.00 4.40	4 3.3924 2.53 50.00 5.97	8 5.06
DISAGREE	14 18.43 8.86 43.75 15.38	18 13.57 11.39 56.25 26.87	32 20.25
NEITHER	13 20.734 8.23 36.11 14.29	23 15.266 14.56 63.89 34.33	36 22.78
NR	60 46.076 37.97 75.00 65.93	20 33.924 12.66 25.00 29.85	80 50.63
STRDISAG	0 1.1519 0.00 0.00 0.00	2 0.8481 1.27 100.00 2.99	2 1.27
Total	91 57.59	67 42.41	158 100.00

PROJECT COMPLETION TIME INCREASED WITH USING CASE TOOLS

STATISTICS FOR TABLE OF COMMENT BY GROUP

Statistic	DF	Value	Prob
Chi-Square	4	22.143	0.000
Likelihood Ratio Chi-Square	4	23.359	0.000
Mantel-Haenszel Chi-Square	1	8.435	0.004
Phi Coefficient		0.374	
Contingency Coefficient		0.351	
Cramer's V		0.374	

Sample Size = 158

WARNING: 40% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

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13. ABSTRACT *(Maximum 200 words)*
This study investigated whether using CASE tools in the requirements analysis phase of software development reduced the software coding errors attributable to requirements analysis. A survey of the population gathered data as to the current practices and efforts in the use of CASE tools. The data was gathered in two groups: a control group and a sample group. The data was analyzed by group and in various combinations to obtain a greater understanding into the population trends and tendencies. The results of the research indicate that the Air Force does not use CASE tools to any great extent. Also, error and cost data are not tracked in a meaningful way either. The conclusion drawn from this research shows that CASE tool use is still in its infancy and needs to begin rapid growth in order to speed up developments and reduce costs with the constantly shrinking budget. The major recommendation by the author is to perform a more detailed study of the population to determine exactly where CASE tools are being used and where improvements need to be made.

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